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To: BDCP.comments@noaa.gov
Subject: comments on BDCP EIR/EIS and IA
Attachments: BDCPcommentsfinal.pdf

Please find attached comments from Save the California Delta Alliance on the draft Bay Delta Conservation Plan, Draft EIR/EIS, and Draft Implementation Agreement. Also attached are several dozen scientific studies cited in the comments and incorporated into the administrative record. The file sizes are too large to include the reports in one email so following emails will contain the reports.

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To: Bay Delta Conservation Plan
responsible state and federal resource agencies

From: Save the California Delta Alliance

Comments on the Draft Bay Delta Conservation Plan
Comments on the Draft Environmental Impact Statement / Environmental Impact Report
Comments on the Draft Implementation Agreement

These comments are submitted on behalf of the Save the California Delta Alliance ("STCDA"). STCDA is headquartered in Discovery Bay, California. STCDA represents the interests of individuals who live and work in the Delta, including those with waterfront homes located in Discovery Bay, Delta related businesses, and many who engage in all kinds of water-related recreation in the Delta. STCDA regularly turns out several hundred enthusiastic members at it its town hall style meetings held in Discovery Bay.

These comments address the Draft Bay Delta Conservation Plan, the Draft Environmental Impact Statement / Environmental Impact Report, and the Draft Implementation Agreement.

References cited herein and attached hereto (and hereby made a part of the administrative record for the BDCP and EIR/EIS) are listed in Appendix 1 hereto.

Thank you for the opportunity to submit these comments and for considering our views.

I. The Project Area In The BDCP and The Project Objectives / Purpose In The EIR/EIS Are Defined In Unreasonably Narrow Terms Frustrating Consideration Of A Reasonable Range Of Alternatives.

The EIR/EIS ("EIR") does not consider broad alternatives or compliments to the twin tunnels. For example, although virtually all sides in the California water debate agree that some form of additional storage is a necessary component of any long-term solution, the EIR does not consider any alternatives that include storage options. Likewise, the Public Draft Bay Delta Conservation Plan ("BDCP") does not include any storage components. Nor does the BDCP include actions outside the narrow geographic scope defined in the Plan Area, which is the statutory Delta and several immediately adjacent areas. *See* BDCP § 1.4.1.

A significant justification for the twin tunnels has been the "little sip, big gulp" rationale. Although this seems to have fallen by the wayside in BDCP promotional efforts of late, it still accurately describes the best policy rationale for the tunnels. By relocating the point of diversion and providing large capacity conveyance it would be possible to draw larger quantities of water at times of abundance (big gulp) thereby allowing diversions to be minimized at times of low flow and critical environmental need (little sip). Sounds good. But it doesn't work without storage. Although the tunnels would provide the ability to divert large quantities of water during peak winter flows, there is currently nowhere to store such diversions. The legislature has ordained that it is state policy to "[i]mprove the water conveyance system and expand statewide water storage." Cal. Water Code § 85020(f). It is no accident that storage and conveyance are tightly yoked in legislative policy. Only with the provision of additional storage capacity can the tunnels actually function as a big gulp little sip device. Yet the BDCP does not contain any storage, and the EIR does not analyze a "tunnels plus storage" alternative.

The feasibility and benefits of expanding storage through increased groundwater recharge is beyond dispute. The necessity to provide additional storage and feasibility of doing so is discussed in more detail in section II below.

The project proponents have attempted to insulate the failure to consider storage and other defects in the BDCP and EIR from challenge by narrowly defining the Project Objectives/Purpose in the EIR and geographic scope in the BDCP. *See* EIR ES.2; BDCP § 1.4.1. However, "a lead agency may not give a project's purpose an artificially narrow definition" in order to arrive at its own foreordained result. *In Re Bay–Delta Programmatic Envtl. Impact Report Coordinated Proceedings*, 43 Cal. 4th 1143, 1166 (2008). An "agency cannot define its objectives in unreasonably narrow terms." *City of Carmel-By-The-Sea v. U.S. Dept. of Transp*, 123 F.3d 1142, 1155 (9th Cir.1997). "Instead, agencies must look hard at the factors relevant to the definition of purpose … . Once an agency has considered the relevant factors, it must define goals for its action that fall somewhere within the range of reasonable choices." *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (9th Cir. 1991).

The Project Objectives provide that a project objective is the "construction and operation of facilities … for the movement of water entering the Delta from the Sacramento Valley watershed to the existing SWP and CVP pumping plants located in the southern Delta." EIR ES-9. This, however, is simply a definition of the twin tunnels. That is an *end result* of the decisional process, not a valid project objective. The project proponents have simply crafted a definition of Project Objectives so narrow that the only result can be to fulfill their own twin tunnel prophecy. However:

> We realize, as we stated before, that the word "reasonable" is not self-defining. Deference, however, does not mean dormancy, and the rule of reason does not give agencies license to fulfill their own prophecies, whatever the parochial impulses that drive them. Environmental impact statements take time and cost money. Yet an agency may not define the objectives of its action in terms so unreasonably narrow that only one alternative from among the environmentally benign ones in the agency's power would accomplish the goals of the agency's action, and the EIS would become a foreordained formality.

Citizens Against Burlington, Inc. v. Busey, 938 F.2d at 196.

The actual purpose of the project is to provide regulatory stability to the operation of the entirety of the state and federal water projects while at the same time lessening and/or mitigating the impact of the operation of the water projects on Delta ecology, and increasing water deliveries with the goal of attaining full contract amounts. These are extraordinarily broad-based policy goals. However, the "Project Objectives" and "Project Purpose" sections in the EIR have been drafted with exceeding precision and care, likely involving many attorney hours in the crafting of these few paragraphs, to limit the range of actions that would fulfill the Project Purpose and Objectives to improving conveyance from the north Delta to the existing export pumps, and providing habitat within the statutory Delta and adjacent areas. *See* EIR ES.2.

The Project Purpose and Project Objectives sections, however, are radically under-inclusive of the actual purposes, as betrayed repeatedly throughout the text of the BDCP: "The overarching goals of the BDCP are to advance the restoration of the ecological functions and productivity in the Delta and restore and protect water supplies provided by the SWP and CVP … ." BDCP 1-5. Successful completion of the BDCP is intended to "afford regulatory stability with respect to the operation of the primary water delivery systems for the State of California." BDCP 1-26. The BDCP "is intended to result in long-term regulatory stability for the state and federal water projects, while furthering the goals of the BDCP to restore and protect ecosystem health, water supply, and water quality." BDCP 1-6. *See also* Draft Implementing Agreement for the Bay Delta Conservation Plan § 2.1.8 ("The overall goal of the BDCP is to restore and protect ecosystem health, water supply, and water quality within a stable regulatory framework.") ("IA").

Surely if the actual goals are to provide regulatory stability for the entire state and federal water projects, protect the drinking water supply and quality for 19,000,000 Californians and millions of acres of irrigated agriculture, and restore the ecosystem health of the largest estuary on the west coast of north America then it is irrational to provide a legal description of those goals in terms so narrow that possible alternatives are limited to exclude almost all components of the state and federal water projects, exclude storage, exclude conservation, and exclude solutions that actually address the problem.

The artificial and impermissible segmenting of Biological Opinions is another attempt to insulate broad effects of the project from challenge by narrowing its legal scope in a way that is inconsistent with its actual scope. BDCP section 1.3.2.2 provides:

> With respect to Reclamation's operation of the CVP, the joint BiOp for the BDCP will cover only those operations that occur after the new water conveyance facilities are operational which is expected to be in 2026. At that time, the joint BDCP BiOp is expected to supersede the existing BiOps (as revised) for the coordinated long-term operation of the SWP and CVP, but only for those operations that occur within the Plan Area. The BiOps on the coordinated long-term operation of the SWP and CVP are expected to continue to provide Section 7 Authorization for operations of the SWP and CVP that occur outside of the BDCP Plan Area.

BDCP 1-9. This segmenting is inconsistent with the fact that "[t]he infrastructure of the state and federal water projects form an integrated system that extends beyond the boundaries of the Delta [and BDCP project area]; as such, the BDCP will affect water operations, species, and habitat both inside and outside the Delta." BDCP 1-3.

For all its discussion of the importance of scale within the fledgling science of restoration ecology, the BDCP does not blush at turning a blind eye to scale when embracing the true dimensions of an issue becomes an impediment to breaking ground on tunnel construction.

II. The BDCP Should Be Revised To Include Storage Through Groundwater Recharge And The EIR Should Analyze A Reasonable Range Of Alternatives That Include Storage Through Groundwater Recharge.

The recently completed Delta Plan, promulgated after years of study and at the charge of the Legislature to set state policy for the Delta, concluded that the key to restoring the health of the Delta and providing a reliable water supply for the state is "Storing Floods to Ride Out Droughts (and Give the Delta a Break)." Delta Plan ES-6. As the Delta Plan is critical to informed decision making for the BDCP and for consideration of a reasonable range of alternatives for the EIR, it is attached in its entirety and made a part of these comments and the administrative record. The Delta Plan further found that groundwater recharge is the best way to achieve additional storage capacity: "using aquifers like bank accounts: to be filled up in wet times, in order that they may be drawn from in dry." Delta Plan ES-7.

A critique of the BDCP by an eminent panel of scientists, commissioned by American Rivers and the Nature Conservancy, Saracino & Mount, LLC, Panel Review of the Draft Bay Delta Plan Prepared for the Nature Conservancy and American Rivers ("Mount Report") also concluded that although one of the objectives of the BDCP is "to increase exports during wet periods and decrease them during dry periods … it does not significantly reduce pressure on the Delta during drier periods." Mount Report 30. The Mount Report suggested that "Expanding potential storage, particularly groundwater storage, would have created considerably more flexibility in exports" allowing more water to be harvested in wet years (big gulp) and conserving environmental flows during periods of scarcity (little sip). Mount Report 22. The Mount Report is attached in its entirety and made a part of these comments and the administrative record.

In Research Brief Issue #102, *Does California Have the Water to Support Population Growth ?* The Public Policy Institute of California Concluded that groundwater storage can provide an additional two million acre feet of "new" water per year. (Attachment ___). Moreover, increasing groundwater storage is the official policy of the state of California. The California Water Plan Update 2005 estimated that through groundwater banking there is "the potential to increase average annual water deliveries by 2 million acre-feet" in conjunction with reoperation of existing surface water reservoirs. California Water Plan Update Chapter 4, page 4-2.

In the report, Groundwater Availability of the Central Valley Aquifer, published by the USGS ("Groundwater Availability"), the authors discuss water banking through groundwater recharge generally and the new groundwater recharge water bank, the Madera Ranch Project, that "would divert floodwaters from the Delta" for storage and future use. Groundwater Availability 108. The Madera Ranch Project involves the banking of CVP water in collaboration between the Madera Irrigation District, A CVP water contractor, and the USBR, a close collaborator on the BDCP. The parties to the BDCP have it well within their means to use additional groundwater banking as a component of the BDCP and it is proven feasible to bank CVP water in groundwater recharge throughout the state.

Groundwater Availability is designed to "be used to identify favorable locations [for groundwater recharge] on a regional scale" and should be of use to BDCP planners in evaluating alternatives that build on the Madera Ranch model. *Id*. Attached are the Madera Ranch federal Record of Decision and Environmental Impact Statement for use in considering additional groundwater banking as an integral component of the BDCP and as part of a reasonable range of alternatives. Also attached are the following scientific reports on groundwater recharge for use in developing alternatives, as listed in Appendix 1.

There is scientific consensus that additional storage through groundwater banking is an essential and feasible element in addressing California's water supply issues and in restoring the health of the Delta. Since these are the two actual goals of the BDCP, there is no reason why groundwater banking should not be a part of the BDCP and failure to consider an alternative that includes groundwater storage is failure to consider a reasonable range of alternatives.

The artificial narrowing of possibilities for infrastructure to exclude groundwater recharge by limiting conveyance to the tunnels and the project area to the Delta by way of an inapt Project Objectives section is no bar to real solutions. Instead, the BDCP proponents "must look hard at the factors relevant to the definition of purpose … . Once an agency has considered the relevant factors, it must define goals for its action that fall somewhere within the range of reasonable choices." *Citizens Against Burlington, Inc. v. Busey*, 938 F.2d 190, 196 (9th Cir. 1991). Here, the range of reasonable choices must include storage, and any reasonable consideration of storage must include groundwater banking.

Investment in infrastructure throughout California to accomplish groundwater recharge is well within the range of reasonable choices available to the BDCP. The water contractor proponents of the BDCP have much of the state's groundwater resources under their collective purview. The water contractors have participated successfully in construction of regional groundwater banking facilities and with USBR in groundwater banking CVP water. As noted in the Delta Plan:

> Statewide water storage capacity, both above and below ground, is currently inadequate, especially south of the Delta, to facilitate export of water at times of surplus when the impacts on the Delta's ecosystem are reduced and the only impediment is lack of available storage capacity (DWR 2009). For example, in 2010, the SWP and CVP pump operations were slowed even though water was available to be pumped at a time when it would not have conflicted with endangered species or other water quality requirements. The SWP and CVP could not convey the surplus water through the Delta at that time because storage capacity south of the Delta was full.

Delta Plan 86.

How much “new” water could be harvested from the existing pumps if lack of storage was addressed through provision of groundwater banking facilities? Construction of the tunnels will cause massive disruption of life in the Delta. The stretch of the Sacramento River and adjacent farmland between Clarksburg and Walnut Grove will be transformed from a peaceful boating and farming landscape into a vast industrial complex supporting tunnel infrastructure. The tens of billions of dollars involved in tunnel construction might be better spent on a series of smaller groundwater recharge projects that would be much less locally disruptive, spare Delta communities from annihilation, and would actually achieve the goals of providing a more reliable water supply to the state, restoring the Bay-Delta ecosystem, and expanding statewide storage capacity as mandated by the legislature.

Or, perhaps, a smaller tunnel project in conjunction with additional storage would be the optimal solution. We will not know until the proponents of the BDCP roll up their sleeves and analyze a reasonable range of storage alternatives—not limited by an artificially narrow project description.

III. The BDCP Should Be Revised To Include Storage / Management With The Sites Reservoir As An Integral Component And The EIR Should Analyze Alternatives Including Sites Reservoir As An Integral Component Of The BDCP.

The proposed Sites Reservoir project, also known as North of Delta Offstream Storage (“NODOS”) is well along in planning and analysis. A preliminary draft environmental impact report and preliminary engineering design were completed in May 2014. Technical difficulties prevented download and inclusion of these documents herewith. They are incorporated by reference and will be provided under separate cover. They are available at http://www.water.ca.gov/storage/northdelta/index.cfm. A technical Memorandum, Sensitivity Analysis of Operation with the BDCP, has not yet been released to the public. The technical memorandum, however, should be currently available to the resource agencies and it is incorporated into the administrative record by reference now even though it is not available to be attached hereto.

NODOS would operate by diverting flows from the Sacramento River at times of high flow through a series of existing irrigation canals to a new surface storage facility. The stored water would then be released back to the river during periods of scarcity. NODOS is well upstream of the Delta, and water released from NODOS could be allocated between in-stream environmental needs and export needs. NODOS could operate in conjunction with any new or existing point of diversion in the Delta, including the tunnels.

NODOS is projected to store up to 1.4 million acre feet. This would add considerable flexibility (which the Mount Report found lacking) to the BDCP for both water supply and environmental needs. The logic of incorporating Sites into the BDCP is obvious. Its technical development has been coterminous with the BDCP. Its function, is to bring to fruition the little sip big gulp approach sorely lacking in the BDCP.

Failure to analyze an alternative that includes Sites makes the range of alternatives analyzed by the BDCP unreasonable. Incorporating Sites would allow the BDCP to become what it must be in order to be successful, a system that can "Store[] Floods to Ride Out Droughts." Delta Plan ES-6.

IV. The BDCP Should Store Floods To Ride Out Droughts.

As currently formulated, the BDCP fails the basic test for providing water supply and environmental solutions because it is a run-of-the-river project. It fails to comply with the coequal goals of the Delta Reform Act, "providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem." Cal. Water Code § 85054. Instead, it must continue to rob environmental needs of water at times of scarcity in order to provide water supply. As such, it simply continues the basic problem rather than offering any solution. The problem, in a nutshell, is that there is an overabundance of water that comes all at once, at the wrong time, in the wrong place, and erratically.

Winter storms drop tremendous amounts of water in very short periods and there is currently no way to harvest or store this water. Instead, it is diverted through flood control structures around the Delta and out to sea.

Attached is a DWR fact sheet entitled Sacramento River Flood Control Project Weirs and Flood Relief Structures. It shows historical diversions at the Moulton, Colusa, Tisdale, Fremont, and Sacramento Weirs. These weirs have combined capacity to divert 588,000 cfs. The Sacramento Weir alone, operating at a river stage of 31 feet, diverts over 31,000 cfs. To put this into perspective, that would be 1 MAF approximately every 16 hours, or the equivalent of the high end of total SWP and CVP yearly diversions (6 MAF) in a period of 4 days. From just one of the five weirs.

The BDCP proposes to spend tens of billions of dollars on new water supply infrastructure. Yet no alternative that would harvest and store even a fraction of this abundance is considered.

V. Issuance Of ESA Permits Is Not A Valid Project Objective And Misdescribes The Project.

The stated objective of "[r]espond[ing] to the application for ITPs for the covered species that authorize take," EIR, ES-8, is not a lawfully permissible project objective or purpose. STCDA first pointed out the confusion around what the project actually is in its comments dated November 16, 2011. Our November 16, 2011, comments are attached and incorporated in full here as to project objectives and purpose and all the other issues raised therein. As we pointed out in those comments, the February 13, 2009, Notice of Intent to prepare an Environmental Impact Statement, 74 Fed. Reg. 7257 ("NOI") states that the proposed federal actions are issuance of ESA permits and implementation of one or more components of the BDCP. However that is not correct. The major federal action is the continued operation of the CVP at increased rates of export through implementation of conveyance improvements/alterations.

See Delta Smelt Consol. Cases, 686 F. Supp. 2d 1026, 1042 (E.D. Cal. 2009) (major federal action was not the issuance of biological opinions but rather "planned coordinated operation of the Projects [CVP] that creates the jeopardy found by the BiOp.").
See also U.S. Fish & Wildlife Service, *Habitat Conservation Plans*, *available at http://library.fws.gov/Pubs9/hcp_section10.pdf* (last visited Nov. 14, 2011) (noting that "[t]he purpose of the incidental take permit is to authorize the incidental take of a listed species, not to authorize the activities that result in the take").

The mis-description of the project in the NOI and Project Objectives section of the EIR are part and parcel of the attempt to portray the tunnels as a "conservation measure" and/or integral part of a habitat conservation plan. The tunnels are a piece of water supply infrastructure. They are an operationally indivisible part of the system that *causes* the take. The vast habitat restoration projects are *mitigation* for operation of the tunnels/CVP/SWP.

The BDCP's pervasive attempts to disguise as a habitat conservation plan a project aimed at increasing water exports through construction of large capacity conveyance facilities violates the Endangered Species Act and numerous other state and federal laws, including the federal Information Quality Act. The attempt to disguise and dissemble also means that the BDCP EIR/EIS fails to provide a stable and accurate project description, in violation of CEQA and NEPA. Rather than foster informed public participation, which is at the heart of CEQA and NEPA, the overly-clever scheme to disseminate misinformation about the true nature of the project is a wanton and willful violation of CEQA and NEPA.

A major Project Objective is to "[r]estore and protect the ability of the SWP and CVP to deliver up to full contract amounts" of water as stated in water delivery contracts. EIR ES-8. The SWP and CVP have never been capable of delivering full contract amounts. Environmental consequences of such delivery and the fact that Delta water is vastly oversubscribed have made such exports impossible. Yet, the tunnels, which would make such vastly increased exports possible, are described as a conservation measure. And the project, including the objective of doubling or tripling water exports, is denominated as a habitat conservation plan. Vastly increasing water exports has nothing to do with conserving habitat or arresting the decline of species.

The two key quantitative guardians of maintaining in-stream flow necessary for environmental protection, X-2 and spring outflow, are made subject to manipulation in order to "minimize water supply effects." BDCP 3.4-11. In other words, the BDCP is a plan to shift water from environmental application to export.

To meet the requirements of state and federal law, the project must be accurately portrayed as a water supply project with attendant habitat restoration as mitigation. As currently formulated, the BDCP is not a Habitat Conservation Plan, within the meaning of the federal Endangered Species Act.

VI. The BDCP Fails To Comply With Water Code Section 85321

California Water Code section 85321 provides that:

> The BDCP shall include a transparent, real-time operational decision-making process in which fishery agencies ensure that applicable biological performance measures are achieved in a timely manner with respect to water system operations.

The intent of the legislature was that real-time decision-making would "ensure that applicable biological performance measures are achieved in a timely manner." However, BDCP section 3.4.1.4.5 employs real-time decision-making as a way of maximizing water exports:

> The CM1 real-time operational decision-making process (real-time operations [RTOs]) allows for short-term adjustments in operations within the range of CM1 criteria described above in Section 3.4.1.4.3, *Flow Criteria*, in order to maximize water supply for SWP and CVP relative to the Annual Operating Plan and its quarterly updates subject to providing the necessary protections for covered species.

BDCP 3.4-26. Species are an afterthought in the BDCP's version of real time operations. They were the *only* concern of the legislature in its specification of real time operations. The legislature said *nothing* about using real-time operations to maximize water supply or adjust the Annual Operating plan.

The BDCP further lists the factors to be considered in adjusting real-time operations as "Covered fish species risks; Necessary actions to avoid adverse effects on covered fish species; Allocations in the year of action or in future years; End of water year storage; San Luis Reservoir low point; Delivery schedules for any SWP or CVP contractor; Actions that could be implemented throughout the year to recover any water supplies reduced by actions taken by the RTO team." BDCP 3.4-26–27. This further emphasis on operation of the tunnels as a water supply device simply confirms the obvious that the tunnels are a water supply device; they are not a conservation measure; nor are they properly described as part of a Habitat Conservation Plan.

All real-time operations adjustments are further strictly limited in that they cannot override the bypass flow criteria established in the BDCP. In other words, no matter what, the water contractors are entitled to receive water in the range permitted by the bypass flow criteria. Real time operations cannot reduce exports beyond these levels. *See* BDCP Chapter 3.4.1.4 and IA § 10.2.2.3. That is not what the legislature ordained. Pasting this additional guarantee of water deliveries into real-time operations that were intended to "ensure that applicable biological performance measures are achieved in a timely manner with respect to water system operations" is contrary to the legislative intent and directive.

To be sure, consistent with its penchant for providing result-oriented legal descriptions that endorse its predetermined course of conduct, the BDCP declares that "[t]he RTO's will satisfy Water Code, section 85321." BDCP 34-26. But saying doesn't make it so. Particularly when no analysis or reasoning is provided as to how, given the glaring disparities described above, the BDCP RTOs satisfy section 85321. Moreover, this one-sentence feat of statutory interpretation, along with the other criteria provided in the BDCP to "implement" section 85321, is an illegal underground regulation with respect to DWR and CDFW. *See* section IV of these comments below.

The Draft IA proffers CDFW's finding that the BDCP complies with section 85321. IA § 4.2.2. However, the drafters have misread the Water Code. Section 85320 is within CDFW's purview (although with limited effect and subject to appeal). Section 85321 is not within CDFW's purview at all. The legislature charged a different state agency (the Delta Stewardship Council) with adjudging in the first instance whether the BDCP complies with section 85321.

VII. The BDCP Lacks Effective Adaptive Management Capability.

Despite the lavish attention paid to general concepts of adaptive management and the celebration of adaptive management as essential to any hope of success of the project, adaptive management is effectively hobbled with respect to the variable most crucial to the success of the plan: water exports.

The IA provides that any "change to a Conservation Measure in a manner that would potentially result in the modification of water supplies [must be] consistent with Section 9.3.7" of the IA. "9.3.7" appears to be a typo and should read 10.3.7. Section 10.3.7, in turn, provides that the "limits and constraints" on adjusting water operations through adaptive management "are set out in Chapter 3.4 and Chapter 8." Chapter 3.4, in turn, contains all the flow criteria, including bypass flows, that have been ardently negotiated into the agreement by the water contractors. Thus, adaptive management is no more available to reduce exports below the flow criteria set out in BDCP section 3.4.1.4.3 than is real time management.

Under withering public criticism, state and federal officials finally backed down from previous agreements (in prior drafts of the BDCP) extracted by the water contractors that reductions in guaranteed levels of exports could only be accomplished through a years-long appeal process that ultimately had to be decided by the Secretaries of the Interior and Commerce and Governor of California (virtually assuring that exports would never be reduced). However, in yet another glaring example of regulatory capture, the water contractors appear to have *improved* their position in the latest BDCP draft.

Under regulatory assurances, the IA specifies that "quantity and timing of [water] delivery" may not be altered under the no surprises rule, and additional measures required of the water contractors to address emergent circumstances may not involve "resource restrictions." IA § 14.1.

By providing an exhaustive list of what constitutes changed circumstances in BDCP section 6.4.2, the BDCP insulates the water contractors from reductions in water exports under the no surprises rule for anything that is not listed. Glaringly absent from the list is the simple proposition that the BDCP will simply not work as projected. Much of the BDCP can, most charitably, be described as at the frontier of scientific knowledge.

The BDCP assumes that wetland creation on farmland that has been reclaimed for over a hundred years and has subsided dozens of feet will be wildly successful. This, despite the fact that no wetland creation in similar circumstances has ever been attempted. It assumes that changes in the point of diversion will achieve all hoped for benefits. None of this is proven from experience. All BDCP projections rely on modeling. And as every good scientist knows, all models are wrong but some models are useful. To make the BDCP models useful to species recovery (rather than lethal to it), the list of changed circumstances should be amended to include "any component of the BDCP not performing as projected," and "jeopardy to any species.

Calling the tunnels a conservation measure has lead to a perversion of the Endangered Species Act whereby the largest single stressor to endangered species, water exports, are guaranteed against reduction (even if reduction is needed to assure species recovery) by the no surprises rule. The ESA and HCP here function as a guarantors of economic benefit to the water contractors and not as tools of species recovery. This is not what Congress intended in enacting the ESA and allowing for HCPs.

If it was not the intent of the state and federal resource agencies to guarantee export levels no matter what, the IA and BDCP should be amended to include the following: "Nothing herein, including but not limited to section 3.4.1.4.3 of the BDCP and section 14.1 of the IA, shall limit or constrain any reduction in water exports determined to be appropriate to achieve the biological goals and objectives through the adaptive management process."

VIII. Along With Much Of The BDCP, DWR's Interpretation Of Section 85321 And Promulgation Of Implementing Criteria Are Illegal Underground Regulations.

California Government Code section 11342.600 provides:

> "Regulation" means every rule, regulation, order, or standard of general application or the amendment, supplement, or revision of any rule, regulation, order, or standard adopted by any state agency to implement, interpret, or make specific the law enforced or administered by it, or to govern its procedure.

California Government Code section 11340.5 in turn provides in pertinent part:

> No state agency shall issue, utilize, enforce, or attempt to enforce any guideline, criterion, bulletin, manual, instruction, order, standard of general application, or other rule, which is a regulation as defined in Section 11342.600, unless the guideline, criterion, bulletin, manual, instruction, order, standard of general application, or other rule has been adopted as a regulation and filed with the Secretary of State pursuant to this chapter.

These provisions of the California Administrative Procedure Act ("APA") apply to the BDCP. The BDCP implements, interprets, and makes specific numerous state laws, including the Delta Reform Act. "The provisions of the BDCP were developed to satisfy the requirements of the Sacramento-San Joaquin Delta Reform Act of 2009, California Water Code (Water Code) § 85300 *et seq*." IA 2.1-9.

The criteria promulgated to implement Water Code section 85321, as discussed in section III of these comments above, are regulations within the meaning of the APA. The criteria selected and the statutory interpretation involved therein (for example, that real time operations cannot override pre-established flow criteria) are subject to the APA. "Absent an express exception, the APA applies to *all* generally applicable administrative interpretations of a statute." *Morning Star Co., v. State Bd, of Equalization*, 38 Cal. 4th 324, 335 (2006) (emphasis added). The sole exception, that the agency's interpretation is "the only legally tenable interpretation of a provision of law,' Cal. Gov. Code § 11340.9(f) cannot apply here. The "lone 'legally tenable' reading of the law applies only in situations where the law can reasonably be read only one way." *Morning Star Co.,* 38 Cal. 4th at 337. Only where "the agency's actions or decisions in applying the law are essentially rote, ministerial, or otherwise patently compelled by, or repetitive of, the statute's plain language," does the exception apply. *Morningstar, 38 Cal. 4th at 336*. The interpretation and implementation of section 85321 here involves an exercise of discretion as to how the statute will be applied. The choices made are by no means the only ones possible under the statute.

The BDCP is not limited to a single project but rather is of general application to an entire class of cases and projects: the BDCP's designated "Covered Activities." This is acknowledged by the parties to the BDCP: The BDCP "[s]ets out a comprehensive approach to coordinating and standardizing applicable requirements for Covered Activities and Associated Federal Actions within the Plan Area." IA 3**.** The BDCP "[e]stablishes a more efficient and effective approach to regulatory compliance with State and federal endangered species laws than through project-by-project, species-by-species planning." Draft Implementing Agreement for the Bay Delta Conservation Plan § 2.1.8.

Where implementation or interpretations "apply generally, rather than in a specific case" the rulemaking provisions of the APA apply. *Morning Star Co., v. State Bd, of Equalization*, 38 Cal. 4th 324, 334 (2006).

The Biological Goals and Objectives and performance standards are further examples of regulations. "'Performance standard' means a regulation that describes an objective with the criteria stated for achieving the objective." Cal Gov. Code § 11342.570.

The BDCP is of monumental public interest and importance, essentially governing the operation of the state's water supply infrastructure and managing the Delta's biological resources over the next fifty years. DWR and CDFW may believe that operating the SWP and managing Delta resources are a matters of internally managing their own infrastructure and not therefore subject to the APA. However, matters "of serious consequence involving an important public interest" cannot escape the requirements of the APA on grounds that the agency is simply determining how it will handle its own internal affairs. *City of San Marcos v. Cal. Highway Com.,* 60 Cal. App. 3d 383, 408 (1976).

By way of further example, CDFW has engaged in underground rulemaking by promulgating section 9.5 of the Draft IA, which specifies procedures and standards of future general application for evaluating "Approval, Adoption or Amendment of Future Plans or Projects," which could result in suspension or revocation of state permits; section 11.1.2, which specifies procedures for "Addressing Failure to Maintain Rough Proportionality."

The instances of underground rulemaking in the BDCP are too numerous and extensive to be exhaustively listed here. Wherever the BDCP implements, interprets, or makes specific state law for general future application, that exercise must comply with the APA.

IX. USFWS And NMFS Have Engaged In Disguised Negotiated Rulemaking With The Water Contractors In Violation Of The Administrative Procedure Act And The Negotiated Rulemaking Act.

All rules issued by federal agencies are subject to the requirements of the federal Administrative Procedure Act. A rule is defined as "an agency statement of general or particular applicability and future effect designed to implement, interpret, or prescribe law or policy or describing the organization, procedure, or practice requirements of an agency" in carrying out its functions. 5 U.S.C. § 551(4). All rules promulgated by federal agencies are subject to notice and comment requirements and publication in the Federal Register, not met here. Further requirements are imposed by federal law on "negotiated rulemaking" whereby federal agencies negotiate, as here, the outcome of the rulemaking process with affected entities. *See generally* the Negotiated Rulemaking Act of 1990, the Federal Advisory Committee Act.

The BDCP and Draft IA contain numerous binding pronouncements of the federal agencies of both general and particular applicability and future effect designed to implement and interpret numerous federal statutes, including the Endangered Species Act, the Fish and Wildlife Coordination Act, the Fish and Wildlife Act of 1956, and the Central Valley Improvement Act. These commitments have been arrived at through negotiation with the Water Contractors. As such, both the BDCP and IA are subject to the Administrative Procedure Act, the Negotiated Rulemaking Act, and the Federal Advisory Committee Act.

Indeed, the entire "adaptive management" component of the BDCP was arrived at through disguised negotiated rulemaking and specifies little more than a procedure for future disguised negotiated rulemaking, intended to subvert the requirements of federal law.

Section 10.2.1.3 of the IA acknowledges that specific outflow criteria are integral to the issuance of take permits. However, it further provides that the outflow criteria may be altered by following a process outlined in section 10.2.1.2, without amending the permits. Likewise, section 10.3.6 specifies that a Conservation Measure or a biological objective may be changed through the adaptive management process set out in section 10.3 of the IA without amending the BDCP or any incidental take permit or other regulatory authorization. First, this is unlawful in any event as permit conditions cannot be altered except by amending the permit. Second, specifying a procedure and substantive criteria that are to be used, and the agency is legally committed to using, in order to alter the terms of permits it issues or to alter the terms of the BDCP is an "agency statement of general or particular applicability and future effect" within the meaning of 5 U.S.C. § 551(4).

Moreover, the parties seem blind to the fact, even if the adaptive management process could be used in the way intended by the IA, that each such change would be subject to environmental review pursuant to NEPA and CEQA.

The management of outflow criteria, the amount of freshwater that flows from the Delta into San Francisco Bay and the Pacific Ocean, is of monumental scope and public importance. The federal agencies have bound themselves to future conduct with respect to their responsibilities in this regard. Section 10.2.1.4 further limits the discretion of the federal agencies to act with regard to outflow through the adaptive management process of the BDCP.

X. The BDCP and Draft IA Violate The Delta Reform Act Because They Contain No Provisions Providing For A Statewide Reduction In Reliance On Delta Water Supplies.

The Draft IA acknowledges that the BDCP must comply with the Delta Reform Act of 2009. Draft IA § 4.2.2. However, the BDCP and IA entirely overlook the Delta Reform Act mandate that "[t]he policy of the State of California is to reduce reliance on the Delta in meeting California's future water needs" through regional self-sufficiency. The pervasive preoccupation with finding a path to reduce outflow criteria conflicts with state policy to reduce reliance on the Delta. Rather it is a formula to reduce water committed to environmental needs so more water can be exported from the Delta and reliance on Delta water can be increased.

XI. The BDCP Lacks Required Assurances of Adequate Funding.

The BDCP relies on funding from new state water bonds, yet to be approved by the legislature for placement on the ballot and of uncertain fate with the voters if placed on the ballot. The water bond described in section 8.3.5.1 is, at best, a political football in the state legislature and likely to contain provisions that bar use of any funds for anything related to the BDCP. Several legislators have announced intentions to place such restrictions on the water bond. The statement that "[t]he BDCP is expected to secure a large portion of the funds allocated [by the new water bond] to Delta sustainability as well as smaller portions of funds allocated to conservation and watershed protection" is at best wishful thinking.

The BDCP's reliance on the use of funds from existing water bonds, already approved, is subject to legal challenge as the monies designated by these bonds were not approved by the voters for construction of the BDCP.

As to federal funding, the BDCP acknowledges that "new federal appropriations would be needed to support the BDCP." BDCP § 8.3.6. A wish that Congress will appropriate funds, or the intent to request funds for your pet project, is not an assurance of adequate funding within the meaning of state and federal law.

The IA statement that "there is no federal position as of this time regarding potential funding obligations of the United States," IA § 13.1.2, is accurate. However, the IA's statement that "[t]he parties anticipate reaching agreement on a federal" share of funding seems blissfully ignorant of the fact that "No Money shall be drawn from the Treasury, but in Consequence of Appropriations made by Law." U.S. Const. Art. 1, Sec. 9, cl. 7. Until appropriated by Congress, federal funding is not assured.

XII. Impacts on Discovery Bay Are Not Analyzed In The EIR And The BDCP Lacks Adequate Monitoring For Discovery Bay.

Representatives from Discovery Bay have requested at BDCP public meetings and through other channels that specific analysis of the project's water quality impacts on Discovery Bay be included in the Draft EIR/EIS. They have not been included. Discovery Bay is different than the rest of the Delta. It consists of 16 shallow water bays, ranging in size from less than an acre to several acres. There is little circulation in the bays. The impacts on water quality in nearby open water sloughs and channels do not translate to water quality impacts in the bays, where reduction in high quality fresh water will translate to much greater degradation of water quality. In order to adequately assess the impacts of the project on water quality in Discovery Bay it will be necessary to perform a fine grain RMA or other analysis of the specific impacts on Discovery Bay. The EIR/EIS fails to adequately address water quality impacts in Discovery Bay.

The EIR/EIS also fails to adequately take account of existing and expected baseline conditions for Discovery Bay and other areas of the Delta where invasive aquatic weeds have significantly hampered circulation and degraded water quality. The weeds result in algal blooms and dangerous reductions in dissolved oxygen. Planned operational changes to the cross-Delta gates, which supply high quality water to the central Delta, including Discovery Bay, must be analyzed at a fine grain level with respect to Discovery Bay and taking account of weed infested baseline conditions.

The mitigation and monitoring/adaptive management program lacks monitoring specific to Discovery Bay. Nearby monitoring stations in open water are inadequate to capture conditions in the sheltered bays.

Submitted,

s/Michael A. Brodsky
Michael A. Brodsky

APPENDIX 1 TO STCDA BDCP COMMENTS

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BDCP1738

SYSTEM-WIDE CONJUNCTIVE WATER MANAGEMENT

DESIGNING SUCCESSFUL GROUNDWATER BANKING PROGRAMS IN THE CENTRAL VALLEY:

LESSONS FROM EXPERIENCE

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The Natural Heritage Institute is a non-profit natural resource conservation organization comprised of technical and legal specialists and dedicated to the improvement of the laws and institutions that manage our natural heritage both domestically and internationally.

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INTRODUCTION

The Central Valley of California, one of the most transformed landscapes on the planet, reveals its history in the manipulation of its waters. The integrated Central Valley water system encompasses most of California, less the drainages east of the Sierra and west of the coastal ranges. Functionally, it runs from Trinity, Shasta and Plumas Counties in the north to the Mexican border in the south and comprises the largest complex of dams, pumps and canals in the world.

As for over-subscribed water systems throughout the American West, policymakers in the Central Valley of California must now devise ways to expand the benefits of a fixed endowment of water and its storage and delivery infrastructure to meet future needs in every sector. The imperative to find "new" water is driven by Congressional mandates, the CALFED Bay Delta Restoration Program planning process and stakeholder demands. Under the Central Valley Project Improvement Act (CVPIA), the Department of Interior is commanded to "develop and implement" a "least-cost" program to supplement and replace the Central Valley Project (CVP) water dedicated to fish and wildlife restoration through, inter alia, improvements in reservoir operations, water banking and conjunctive use (§§3406(b)(3) and 3408(j)). The CVPIA’s Anadromous Fish Restoration Program (AFRP) will require water for instream flow enhancement. The new Environmental Water Account—perhaps the singular triumph of the CALFED Bay-Delta Restoration Program—will require some 350,000 acre-feet of water per year for restoration of aquatic habitats. CALFED’s commitment to restoration of fishery flows in the San Joaquin River below Friant Dam will also require "new" water if current contract deliveries from the Friant Unit of the CVP are to be maintained. The CVP is unable to make full deliveries under its contracts with agricultural water districts south of the delta in most years. And, municipal water supply agencies are seeking dilution water to improve water quality instead of making large investments in treatment facilities. In response to these needs, a core objective of the CALFED Program is to improve water supply reliability for all sectors. Groundwater banking comprises the largest component of the new storage envisioned.

This paper illuminates the institutional arrangements for actualizing that opportunity. Particularly, we are interested in arrangements to integrate groundwater storage into the existing surface water storage and delivery system of the Central Valley. Such groundwater banking projects would actively recharge the aquifer with imported foreign surface water originating from a source not hydrologically connected to the groundwater banking site.[1] In this important respect, such projects are to be distinguished from the conventional development of native groundwater for purely local use.

The scenario of greatest interest involves reoperation of the eleven existing terminal reservoirs of the Central Valley tributaries. These reservoirs are owned and operated by the U.S. Bureau of Reclamation, the California Department of Water Resources, the U.S. Army Corps of Engineers and several municipal and agricultural water districts. The storage and release regime of these reservoirs would be modified to allow them to capture a larger fraction of the peak flow events as they move through the system, and carry this water over for use in years of lower than average run-off. This additional storage capacity would be created by moving a substantial portion of the reservoir water into groundwater basins with currently unutilized aquifer storage capacity, such as cones of depression from historic groundwater exploitation. Thus, reservoirs would be reoperated to provide source water to recharge the groundwater banks with water that would otherwise spill for flood control. The sequence could also be reversed in the case of full aquifers, most commonly found in the Sacramento Valley, such that native groundwater is first extracted and exported to create storage space, and then subsequently replenished from an imported surface source. The imported or "new" water would be injected underground or applied to spreading grounds where it could percolate into the aquifer. Later, the banked water would be recovered and reintegrated into the existing (or enhanced) water delivery system to provide supply benefits to non-overlying users during drier years. The recharge and recovery would be conducted by (or under contract with) an overlying landowner, water district or groundwater management authority. The Kern Water Bank and the Arvin Edison/MWD arrangement are examples of this type of conjunctive use project.

Alternatively, the recharge could be accomplished through substitution of surface water supplies for existing groundwater usage, with recovery accomplished by reversing the arrangement. From an aquifer mass balance standpoint, such *in lieu* storage arrangements are indistinguishable from active recharge. In effect, groundwater users agree to forbear pumping groundwater during wetter years and instead use surface water imports to which they would not otherwise have access. The conjunctive use program then purchases groundwater pumped by overlying landowners during drier years, over and above their customary extractions, and exports it from the basin. This differs from groundwater substitution projects, which do not involve the export of groundwater or its replenishment through imported recharge water. In lieu banking may be more appropriate than recharge by percolation in areas with low-permeability soils, such as the east side of the Sacramento Valley. The Semitropic Groundwater Banking Program in the San Joaquin Valley is an example of *in lieu* recharge.

Active recharge and *in lieu* groundwater banking must, as a practical necessity, be developed with the cooperation and consent of overlying landowners, water districts and groundwater management authorities. Indeed, the recharge and recovery operations will generally be conducted by such local interests. These arrangements will require the consent and participation of at least four types of entities: (1) the reservoir owner who would consent to change the current storage and release regime in order to generate source water for groundwater banking; (2) the local groundwater management authority which would participate by, in effect, "renting" aquifer space for temporary storage of the imported recharge water;[2] (3) the operators of the infrastructure needed to move the water from reservoir to groundwater bank to point of end-use; and (4) the end-use beneficiaries who would pay for the new yield and thereby generate a revenue stream to compensate the reservoir owner and the groundwater banker. With the concurrence of these stakeholders, a project is likely to succeed in spite of the institutional complexities described in this paper. Without that concurrence, a project is likely to fail even if these complexities are overcome.

The terms, conditions and assurances to satisfy the second category of participant—the local groundwater management authority and its existing groundwater users—are at once the most elusive and the most critical elements for success. "Local control" of the banking operations is axiomatic but not well defined in practice. Institutional design is an exercise in defining who controls what and how, that is, in detailing the mechanisms for local control. Designing workable mechanisms for local operation of groundwater banks should be markedly easier where the local groundwater users do not have rights to the recovered groundwater because it has been imported into the basin, compared to the case where local groundwater is developed for export.

There is no realistic prospect of "outside" interests imposing a water bank on reluctant local communities. The need for institutional arrangements that can avoid or arbitrate disputes arises not because of the threat that "outsiders" may seek to impose a water bank on unwilling local groundwater communities, but because of the very real possibility of disagreements among the local landowners themselves. Indeed, that has been the etiology of most groundwater banking controversies historically in California, such as the Department of Water Resources' 1994 Emergency Drought Water Bank in Butte County and the Madera Ranch and Azurix projects in Madera County. However, projects will also require consensual contractual arrangements with to two types of "outsiders": a source water rights holder (i.e., a reservoir operator) and one or more end-use beneficiaries. Sufficient financial and/or hydrologic rewards must accrue to each of these parties in order to induce their participation in the banking scheme.

The keystone technical issues in groundwater banking include determining the aquifer baseline conditions, including the extent of unsaturated aquifer space, and recovering the imported water without causing injury to other groundwater users. These issues are fraught with uncertainty. Aquifer geometries are usually rather poorly defined, and subsurface water interacts with surface flows. Water in aquifers is not static, but is in perpetual slow motion along gradients and in response to differential hydrostatic pressures. Artificial recharge alters the hydrostatic pressures within the groundwater basin and may cause some of the native groundwater to become unrecoverable to overlying landowners (by migrating to a salt sink or a surface water body, for example). There is no guarantee that any particular molecule deposited in a groundwater bank in one year will be physically available to extract in a future year. Indeed, it is presumed that some percentage of the banked water cannot be recovered without causing adverse impacts on other users of groundwater in the same basin. That percentage is itself uncertain. However, the potential for injury to other groundwater users may be mitigated or avoided by adjusting the rates, volumes and locations of the extraction wells and the residence time of the banked water. Under the "extract then replenish" scenario, care must be taken not to deplete hydrologically connected streamflows[3] or lower the groundwater table below the level of existing wells.

Water quality, too, is often an issue in groundwater banking. Commingling lower quality recharge water with *in situ* groundwater may constitute a legally cognizable injury to other groundwater users. This could be a problem with recycled municipal wastewater or surface water routed through the Sacramento-San Joaquin Delta, for instance. Even pure recharge water could mobilize salts and agricultural chemicals in groundwater basins that have historically been heavily irrigated. Where feasible, conveying reservoir water directly into groundwater banks, without routing it through the Sacramento-San Joaquin Delta, should avoid water problems since Sierra snowmelt is the cleanest water in the system.

Commonly, impacts that would otherwise constitute legally cognizable injury may be mitigated or avoided through implementation of a "physical solution", which may be incorporated into the project design or imposed by the State Water Resources Control Board or a court.[4] For example, water users could be made whole through delivery of an alternate source of water of equal quality and quantity to that which they are entitled. Additionally, a well owner who has to sink a deeper well could be reimbursed for the increased well construction and pumping costs. Of course, there may also be limitations independent of the no injury rule on the extent to which adverse environmental impacts are allowed. Depending on the nature and severity of the change, adverse impacts on groundwater quality may not be allowable even if the affected well owners accept compensation.

As an early step in designing workable institutional arrangements, this system-wide investigation studied seven historic conjunctive use projects—some successful and some not. Our purpose in studying these cases was to distill the variables in the design and execution of conjunctive use projects that militate in favor of success of a project. The next section of this report explains the scope and methodology of the case analyses. Section Three presents the

Findings and Conclusions that we have distilled from the case studies. Section Four discusses the outstanding legal issues and uncertainties that may warrant attention from the State Water Resources Control Board or the State Legislature to facilitate conjunctive water management in California. In Section Five, the eight cases are presented in detail.

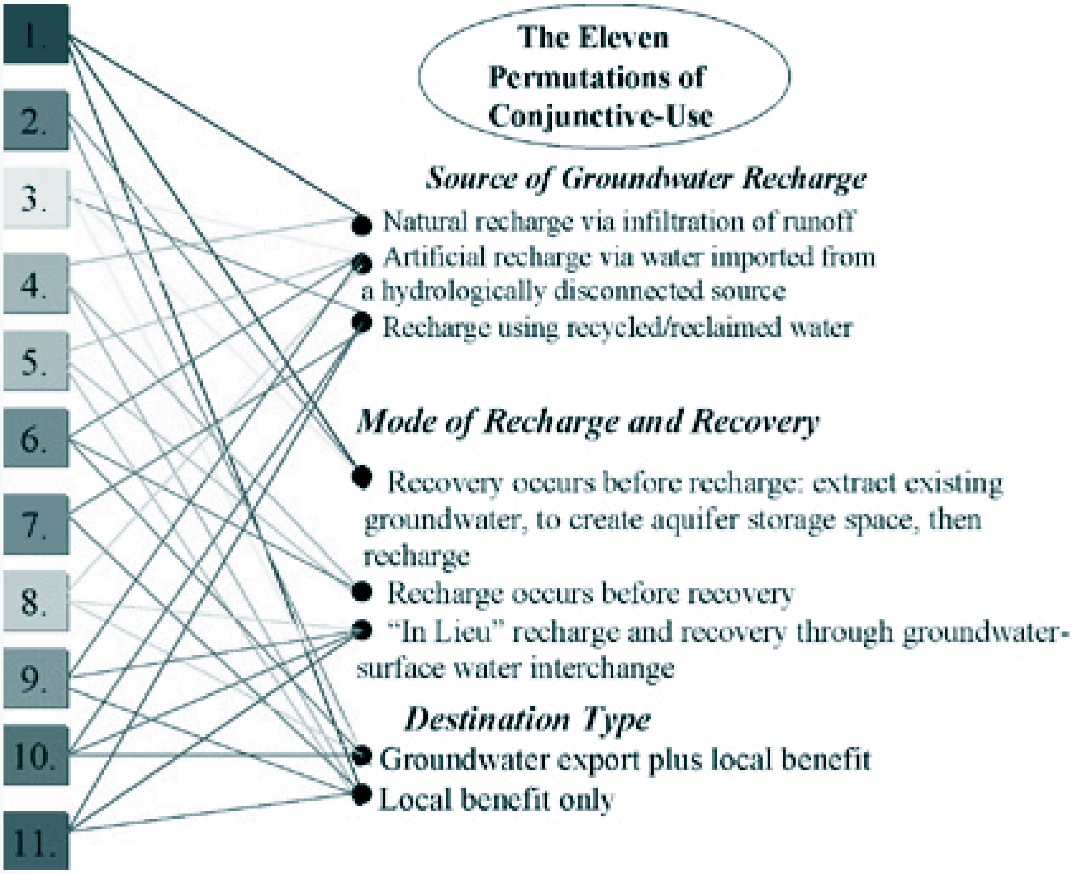
Finally, in Section Six, we sketch hypothetical arrangements based on our research and findings. These arrangements represent the study team's best judgment as to how a program could be set up to satisfy local interests and concerns such that groundwater management authorities would be willing—even eager—to participate in actively recharged groundwater banking projects. The hypothetical arrangements will be the subject of detailed discussions with the local groundwater communities—water users, water districts, groundwater management officials, political leaders and other stakeholders—in a series of "ground-truthing" sessions. In these, we will present the hypothetical arrangements and solicit comments, criticisms and (most important) counterproposals on the essential features and details of institutional arrangements. The end product of this process will be a high-confidence portrait of an ideal local institutional arrangement that should greatly improve the prospects for successful groundwater banking projects throughout the Central Valley waterscape.

SCOPE AND METHODOLOGY

As noted, our purpose in studying the current, high-profile efforts at conjunctive water management in the Central Valley is to emulate the design features that make for successful projects and avoid those that tend to produce failures. For this analysis, we are primarily interested in the institutional factors, but also remain alert to hydrologic, economic or geographic attributes that appear to correlate strongly with success. The term "institutional factors" refers to the mechanisms that:

> - Create and protect the legal rights of the conjunctive water manager to obtain water from the surface reservoir or stream, convey it to the groundwater banking site, recharge the groundwater, extract the stored water and reconvey it to points of end-use;
> - Avoid, minimize, mitigate or compensate for adverse impacts on those holding rights to the waters, reservoirs, conveyance systems, aquifers, and overlying lands involved in conjunctive water projects; and
> - Anticipate and avoid or mitigate potential environmental impacts associated with moving water into and out of groundwater banks.

In tracking these features and variables, the case studies are conscious of the differences in projects with respect to sources of groundwater recharge, modes of banking, and end-use destinations. By combining the alternatives for each of these components, it is possible to describe eleven different types of groundwater storage projects. Depending on their features, these may call for rather different institutional arrangements. The permutations are displayed graphically below:



It is important to note that actively recharged groundwater banks—the species of conjunctive use that is the focus of the system-wide conjunctive water management investigation—involve only three of these possible eleven options. These are the options that provide the largest yield benefits to the broadest range of water stakeholders, are more likely to benefit than harm existing groundwater users, and provide the greatest potential for environmental restoration. As we have previously noted, the system-wide program would utilize artificial recharge from water imported from a hydrologically disconnected source—namely, a terminal reservoir. The destination of most (but not all) of the stored groundwater would be the integrated Central Valley water system, not just the overlying lands. To be sure, some of the water may be left behind to compensate the local groundwater basin for providing temporary storage services, but the objective of the program is to provide system-wide benefits. In regard to the sequence of recharge and recovery, three alternatives would be utilized:

> - Where a pre-existing cone of depression exists, the aquifer would be recharged first and discharged later.
>
> - Where the aquifer is already full, extraction would occur first (to create storage space) and then the "hole" would be replenished with imported recharge water.
>
> - In areas where soils are relatively impermeable to percolation and excess capacity exists to deliver both surface water and to utilize groundwater (or where that condition could easily be created), recharge and recovery could be accomplished through *in lieu* arrangements. In these projects, groundwater would be banked by substituting surface water for groundwater that would otherwise be pumped. It would then be extracted by substituting groundwater pumping for a surface water delivery that would otherwise be provided.

None of the cases analyzed in this document involve the active recharge of a groundwater bank with water generated from reservoir reoperation simply because no such conjunctive use project has yet been implemented in California.[5] Therefore, to learn how to design such a program, we must extrapolate from the lessons distilled from the types of cases that have occurred. In fact, the system-wide proposal has a number of distinct advantages over historic projects from the standpoint of protecting local interests. These are described below.

Favorable Design Features of the System-Wide Approach

The system-wide approach accepts as a design constraints that water must be recharged and recovered in a manner that avoids any injury to legal users of water and in a manner that would provide a net improvement to aquatic environments. Some of the ways these constraints would be observed include:

> - The program would bank water imported from reservoirs rather than exploiting native groundwater for export. This greatly simplifies the requirement of avoiding injury to legal users of groundwater because the water that is extracted and exported is not subject to the correlative rights that attach to native groundwater. The importer enjoys a paramount right to extract the banked water because it would not have been available to the groundwater basin at all but for the act of importation. Indeed, the recharge of the aquifer will benefit all groundwater users in the basin because the water table will be elevated and, therefore, pumping costs will be reduced. The major hydrologic issues associated with avoiding injury go to the rate, timing, location and volume of extractions. To be sure, these issues are somewhat more complicated where some native groundwater must first be extracted to create aquifer storage space and then

replenished with imported water. The hypothetical arrangements set forth at the end of this report propose ways that these types of projects can operate to avoid any significant likelihood of injury to legal users of groundwater.

u The recharge and recovery operations would be controlled by the local groundwater management authority. This might be a local water district, a local groundwater authority established through a county ordinance, a joint powers authority, or an entity created by special act of the legislature. The banking and extraction facilities would either be operated by that local authority or under voluntary contractual arrangements with it, specifying the terms and conditions and the compensation. Local control is therefore taken as axiomatic.

u Water tables would not be allowed to rise to the point where groundwater could invade root zones or surface structures or reduce the natural infiltration capacity of the aquifer. Conversely, water tables would not be allowed to fall below the levels that would occur in the absence of a conjunctive use program. The program would only counteract, not contribute to, subsidence. Phreatophytic habitats would only be enhanced, not degraded, by an elevated water table in the banking region.

u The program would utilize Sierra snowmelt, captured in foothill reservoirs, as the source of recharge water. This is the highest quality water available within the system. Water quality issues would arise only to the extent that this water is commingled with lower quality water, such as delta waters, en route to the recharge facilities.

Thus, actively recharged groundwater banks would avoid many of the problems and issues associated with the development of native groundwater or with groundwater substitution projects. However, the mitigation devices and institutional arrangements illustrated by the cases examined in this paper are instructive in designing all types of conjunctive use projects.

Types of Groundwater Storage Projects Studied

Of the eleven possible permutations of conjunctive use, the cases represent the following groundwater storage typologies:

u Native groundwater export projects utilizing full aquifers and natural recharge. These are a type of groundwater substitution project where existing surface water users are paid to forego those deliveries and pump groundwater instead. This allows their surface water entitlement to be delivered to a user in a different basin. The DWR Drought Water Bank and the DWR Supplemental Water Purchase Program are the only two examples of this type of project of which we are aware, and they are included as case studies. In the future, such projects can be envisioned at the Stony Creek fan, the Butte Basin and the Conaway Ranch area—all sites in the Sacramento Valley.

u Local benefit projects where recharge from imported water sources occurs before recovery. Projects of this type include the Kern Water Bank, SNAGMA, Semitropic's groundwater banking program, Berenda-Mesa's groundwater banking program, and the project of the Mojave Water Agency.

u Groundwater export projects where recharge from imported water sources occurs before recovery. Projects of this type include Madera Ranch, EBMUD-San Joaquin County, Arvin-Edison-MWD, and the Semitropic project.

We did not investigate local benefit projects where recharge is accomplished with recycled or reclaimed water. The water quality issues dominate in these projects. We also did not investigate local benefit projects utilizing full aquifers where storage space has to be created by extracting groundwater first, and then replenished through natural recharge. There are no currently operating projects of this type outside of adjudicated basins (such as the Raymond basin, the San Gabriel basin and the Orange County Water District). However, we may see examples of this type in the future, such as the project that the Glen Colusa Irrigation District is investigating. Finally, we did not study local benefit projects where recharge from native water sources occurs before recovery. The Merced Irrigation District/City of Merced project, the Clovis/Fresno project, and the Bakersfield emergency banking project are all of this type. While these projects are worthwhile, they do not offer a wealth of lessons from the standpoint of transferable institutional design features.

Risk Factors Analyzed

Each of the case studies evaluates how the project has succeeded or failed in dealing with the hydrologic, water quality, financial, legal and political risks associated with groundwater banking. Where pertinent, we specifically looked at how each project dealt with the following factors:

1 HYDROGEOLOGIC RISKS:

A) The risk of losing stored water because it "leaks" out of the aquifer and cannot be recovered without adverse impacts on other groundwater users in that aquifer.

B) The risk of losing stored water because it is not possible to increase the pumping rate at times of extraction without adversely affecting other groundwater pumpers in that aquifer.

C) The risk that raising the groundwater table will reduce natural infiltration and thereby deprive other groundwater users of natural recharge water.

D) The risk that raising the groundwater table will invade the root zone of permanent crops or create phreatophytic vegetation that is subject to regulation as a wetland.

2) WATER QUALITY RISKS:

A) The risk of degrading the receiving aquifer with lower quality recharge water (such as water that is routed through the delta).

B) The risk of leaching soil contaminants into the stored water.

3) FINANCIAL RISKS:

A) The risk that delivery of banked water through exchange arrangements will not be accomplished due to delta pumping restrictions.

B) The risk that energy requirements for pumping will be increased.

4) LEGAL RISKS:

A) The risk that groundwater storage or extraction would cause injury to other legal users of groundwater.

B) The risk that groundwater storage would limit the rights of current or future users of groundwater in the same basin.

C) The risk that the conjunctive use project would take legal action against other groundwater users to protect its rights to extract groundwater.

5) Political risks associated with adverse community reactions in light of real or perceived injuries to local groundwater interests.

For all of these considerations, each case study assesses how successful the project has been, as well as how it could have been designed to deal with these factors more successfully.

Study Plan

The study team progressed through the following sequence of steps:

1) Select the cases:
We screened the historical attempts at groundwater storage and selected a subset of seven cases that are representative of the various possible configurations and variables. The selected cases are regionally significant, illustrate a variety of stakeholder interactions, and are particularly rich in design lessons. The projects illustrate both successful and unsuccessful factors and strategies. All are located within the Sacramento and San Joaquin basins. Projects outside of the Central Valley or in adjudicated groundwater basins were eliminated because they present different and generally easier challenges. Projects were also selected because they provide interesting and lesson-rich contrasts. For example, the Sacramento North Area Groundwater Management Agency/American River Basin Cooperating Agencies Conjunctive Use Program (SNAGMA/ARBCA) and the Kern Water Bank were selected because they both represent successful large-scale programs but have significant differences in the end-uses of water and the types of participating stakeholder groups. Conversely, sometimes successful and unsuccessful cases share similar physical features and socio-economic settings. These cases provide further insight into the variables that can affect the success of conjunctive use programs.

2) Review the literature:
For each selected case, the study team members gathered and reviewed the literature and documents generated by the project and by external commentators, reviewers and critics.

3) Describe the physical features and design characteristics of each project:
The researchers abstracted from this literature the information on the project that is responsive to the issues and questions posed in this report. For easy comparison, the project characteristics are displayed in matrix format in Apendicies A-G.

4) Conduct interviews:
For each project, the researchers interviewed project proponents and opponents, informed community and political leaders, affected water district managers and personnel, and local spokespersons for agriculture and the groundwater users.

5) Write narrative case studies:
The case studies can be found in Section Five of this report.

6) Derive findings and conclusion:
Findings and conclusions are set forth in Section Three of this report.

7) FORMULATE HYPOTHETICAL PROJECT DESIGN RECOMMENDATIONS:

The hypothetical arrangements are outlined in Section Six of this report.

8) TEST THE HYPOTHESES IN FOCUS GROUP SESSIONS:

Focus group sessions will be convened after this report has been circulated for review. They will be conducted in the groundwater basins that have been identified as promising locations for groundwater banking, based on hydrogeologic investigations that are reported in a separate document. The purpose of the focus group sessions is to confirm, adjust and refine the hypothetical design recommendations.

FINDINGS AND CONCLUSIONS

Measures of Success

As we have noted previously, conjunctive use projects must provide sufficient local benefits to prompt the local groundwater management entity or individual landowners to enter the deal. Thus, the success of the project depends upon financial or water supply rewards at the local level. The program must also insulate the local groundwater users and managers from perceptible risks. These risk factors are of three types: (1) hydrologic (the risk that either the quantity or quality of groundwater currently available for local use will be diminished); (2) financial (the risk that the energy costs of lifting groundwater will be increased); and (3) legal (the risk that existing rights and entitlements will be clouded or will have to be defended). Perceived risks must be taken at face value in the groundwater arena. Thus, risk management is more important than risk assessment in the design of conjunctive management institutions.

The design features summarized below provide a template for successful projects in settings throughout the Central Valley. Successful programs:

> - Are financially rewarding for the water district, management authority or local landowners that operate the bank.[6]
> - Are financially and/or hydrologically rewarding for local groundwater users.
> - Pose no unacceptable hydrologic or legal risk to local groundwater users, the banking district or the local groundwater management authority.
> - Involve local communities and stakeholders throughout the process of developing and implementing the groundwater banking plan.

Factors in Successful Programs

Projects that the case studies reveal to be successful under the above criteria include the Semitropic, Arvin-Edison, Kern Water Bank and SNAGMA projects. There are many common features to these projects that account for their success. We have organized analysis of these features under topical headings below.

CHARACTER OF BANKED WATER

In all successful cases, the banked water is imported from a hydrologically disconnected source. Thus, the banked water would not otherwise be available to the groundwater basin. None of the successful projects involved the development of native groundwater either alone or as part of a groundwater substitution scheme. In the case of the Semitropic groundwater bank, the source water is state or federal project water belonging to Metropolitan Water District (MWD) and Santa Clara Valley Water District (SCVWD) or supplies imported by Vidler Water Company or Alameda County Water District. In the case of Arvin-Edison, the source water is MWD's State Water Project (SWP) entitlement or flood releases from Friant Dam. By contrast, DWR's unsuccessful 1994 Emergency Drought Water Bank in the Sacramento Valley failed in part because it did involve the substitution of native groundwater for State Water Project deliveries.

Also, in the majority of successful cases, the recharge water is of better quality than the *in situ* groundwater at the banking site.

SITE THE BANK WITHIN THE BOUNDARIES OF A LOCAL WATER MANAGEMENT AGENCY

One of the factors most determinative of the success of a groundwater bank is locating it within a water district, joint powers authority or other local groundwater management authority that genuinely represents the interests of affected landowners.

AVOIDING HYDROLOGIC RISKS

Successful programs such as Semitropic and Arvin-Edison used a number of devices to ensure that neighboring groundwater users will not be adversely affected during the recovery operations. These fall into three categories: (1) limits on operations to avoid adverse impacts on other groundwater users; (2) arrangements to compensate for impacts or absorb the costs of measures to avoid impacts; and (3) information systems sufficient to avoid adverse impacts. Examples of measures to minimize hydrologic risks are detailed below.

> **Volumetric limits:** In these successful projects, the volume of extractions is limited to a fixed percentage of the water percolated into the groundwater bank to account for presumed losses due to evaporation from spreading basins and migration out of the aquifer. The percentage, fixed at 90% in the Semitropic and Arvin-Edison examples, is subject to adjustment based on monitoring data.
>
> **Water table limits:** For example, under its "fifteen-foot/three-year" rule, Semitropic will not make groundwater withdrawals that cause the average groundwater level in an area to decline by over fifteen feet compared to what would have occurred without the project over a three-year period.
>
> **Limits on the placement of extraction wells:** The extraction wells are located so as to avoid significant impacts on the pump lifts of neighboring groundwater users.[7] The groundwater bank should also be located to avoid interaction with surface stream systems (unless a purpose of the bank is to increase base flows).
>
> **Limits on the timing of pumping:** It may be advisable to restrict operation of recovery wells to the off-season or to off-days for irrigation pumping. Recovery can also be restricted until a specified period after recharge to allow sufficient time for the water to percolate into the aquifer.
>
> **Curtail pumping:** If its pumping interferes with neighboring wells, the project may be required to either stop pumping or compensate for the interference.
>
> **Compensation:** The project can guarantee neighboring groundwater users that it will compensate them for any costs occasioned by increased power requirements for pumping compared to the historic baseline, with an easy and fast claims processing procedure.
>
> **Provide alternative water supplies:** An alternative to monetary compensation is a guarantee of a substitute water supply to impacted overlying users. For instance, a groundwater bank could agree to supply neighbors with water out of the bank in exchange for their forbearance from pumping, perhaps including the right to use the neighbors' wells as extraction facilities.
>
> **Assume responsibility for deepening wells** to avoid impacts or restrict recovery wells to those shallower than the neighbors'.
>
> **Develop good baseline information:** Designing a project that can avoid hydrologic impacts may depend crucially on improving the understanding of pre-project groundwater conditions including the drawdown tolerances (pumping thresholds) of existing wells.

MONITORING PROGRAM

The successful conjunctive use projects have established monitoring programs run by a committee that includes potentially affected landowners. The monitoring committee has the right to hire its own expert consultants to assist in data collection and analysis. In the case of the Kern Water Bank, the committee oversees a comprehensive monitoring program to determine groundwater levels and water quality under project and non-project conditions and has the power to modify operations if they are found to be inconsistent with local groundwater management plans.[8] In the case of Semitropic, the monitoring program has the right to curtail extractions if certain benchmarks are hit in the monitoring results.

AVOIDANCE OF LEGAL RISKS: DISPUTE RESOLUTION PROCEDURES

One technique that emerges from the case studies is entrusting dispute resolution to the monitoring committee, which includes local groundwater users. Another option, exemplified by the Semitropic bank, is to submit factual disputes to binding arbitration before a registered civil engineer with a background in groundwater hydrology.

LOCAL BENEFITS

As stated previously, sufficient local benefits are an integral part of successful conjunctive use projects. These can be in the form of cash payments or a share of the banked water. However, the case studies show that first priority to the banked water does not have to be allocated to the banking district, provided that the benefits to that district and its members are otherwise sufficient to induce its voluntary participation. In fact, successful case studies show a myriad of arrangements that are the product of negotiated agreements among the parties.

In the Kern Water Bank, local water supply agencies are accorded a "right of first refusal" on extractions from the bank and a first call on its recharge capacity. By contrast, in the Semitropic example, the agreements do not reserve to Semitropic a first right to extract water or to use the extraction facilities or other facilities of the program. Instead, the first right to extract is given to the Banking Partners. In the Arvin-Edison program, the district has the first right to use extraction facilities to meet its own needs while MWD has a priority over others who enter the banking arrangement later.

FINANCIAL ARRANGEMENTS

The contractual arrangements must assure the water district or groundwater management authority that all foreseeable costs of operating the program (conveyance, recharge, extraction, reintegration) will be defrayed by the beneficiaries or some other party. Thus, Semitropic Water District, for instance, receives payments when water is stored and when water is extracted, including its energy costs and its operation and maintenance costs. Semitropic's banking partners have made the project essentially cost and risk free for Semitropic, while giving the district numerous facilities and other benefits. From a financial perspective, the program has been very successful. Revenue generated from Semitropic's banking program has in part allowed the district to reduce water charges to its landowners from almost $60 per acre-foot in 1995 to less than $50 per acre-foot in 1998.

The Arvin-Edison program illustrates another device for managing financial risks. The agreement insulates the district from the risk that it will be unable to deliver the stored water to the intended beneficiary due to constraints beyond its control, such as pumping constraints in the delta which may prevent it from exchanging banked water for project deliveries. In the Arvin-Edison example, the district is entitled to buy back the banked water at its marginal cost of alternative supplies in the event that delivery cannot be accomplished. As in its arrangement with Semitropic, the Metropolitan Water District of Southern California (MWD) was willing to make the project essentially cost and risk free for Arvin-Edison while providing the district with substantial benefits.

Local Control

In all successful cases analyzed, the overlying water district is in charge of the recharge and recovery operations. For agricultural water district bankers, this construct seems to work because landowners who rely on groundwater are represented in the governance of the water district. This provides a measure of local control that lends comfort and confidence to the groundwater users. It is notable also that, in most cases, the active outreach of the district's president and/or general manager was a key to overcoming the landowners' initial apprehension regarding a banking program. For instance, in the examples of the Kern Water Bank, Semitropic, and SNAGMA, local officials understood and supported the program and did a good job of explaining it to the members of the district and surrounding landowners.

Institutional Cohesion

Cohesiveness among water agencies and a common planning framework are helpful in creating successful groundwater banking projects. In the SNAGMA case, the General Plan for the region provided that common framework. In addition, the water agencies within the Sacramento area have multiple forums for communication and cooperation. In the Kern Water Bank example as well, the water agencies work together in the Kern County Water Agency, which serves as an umbrella organization and represents local interests at the state level. It is notable that Paramount Farms' involvement in the Kern Water Bank negotiation process was beneficial, as private sector organizations often have more flexibility than do public agencies.

Local Support and Public Involvement

The consistent and meaningful involvement of the range of local stakeholders is a common element of successful programs. While it is to be expected that landowners will have some concerns, the more supportive and cooperative they become, the greater the likelihood that the project will succeed. Efforts to involve landowners and other stakeholders in project development, implementation and monitoring help to garner their support. Leadership by local officials also plays an important role.

Involvement of local stakeholders in the process of building consensus and forming collaborative organizations is an important element of the SNAGMA project. This case demonstrates that, while the process may not be simple or quick, interest-based negotiation is an effective method to address these complex issues. Taking the time to train and educate the participating stakeholders, as well as using professional facilitation, increases the likelihood of success. In the Kern Water Bank example, the monitoring committee offers a structure and a forum for the involvement of overlying users adjacent to the project and an opportunity for their concerns to be addressed.

Ease in garnering local support is often due to a region's history with water banking projects and water management efforts in general. For example, internal opposition to Arvin-Edison's conjunctive use program has been non-existent. While some opposition has come from outside the district, the landowners inside the district were already familiar with conjunctive use and have seen it operate successfully in their district for almost fifty years. Notably, Arvin-Edison is a district that was originally formed to conduct conjunctive use operations for the benefit of its own landowners. Thus, the concept of conjunctive use and/or groundwater banking was never new or foreign to landowners in the district. In the example of the Kern Water Bank, water banking projects are common in the area and tend to be accepted as necessary to preserve and enhance the local economy. Also, the Bank has done an effective job of creating habitat and enhancing the natural environment, thus winning over environmental stakeholders.

ENVIRONMENTAL DOCUMENTATION

The Semitropic case proved to be fairly easy to implement environmentally, and the Arvin-Edison project only had to comply with CEQA, not NEPA, and was implemented with an Initial Study and Negative Declaration instead of an EIR or EIS. These more streamlined processes for environmental documentation probably increased the likelihood of success for these projects.

Factors in Unsuccessful Programs

By the criteria set forth at the beginning of this chapter, the 1994 DWR Drought Water Bank in Butte County, the Madera Ranch case, and the initial EBMUD-San Joaquin County negotiations must be regarded as unsuccessful efforts, at least so far. We can learn important design lessons from these cases as well. The most salient findings are summarized below.

CHARACTER OF BANKED WATER

According to the case studies, projects that rely on passive recharge (natural infiltration), such as the 1994 Emergency Drought Water Bank, are perilous. These groundwater substitution programs are particularly likely to be unacceptable when the water exporter does not have the power to curtail pumping in the event of injury to others, as in the Butte County example. However, this does not mean that projects that feature active recharge with imported water are always successful, as the San Joaquin County example shows. In those cases, the failure results from factors other than the source of the banked water. Banking water of inferior quality compared to the native groundwater, as was the case in the Madera Ranch project, is problematic and more likely to suffer local opposition.

TECHNICAL ANALYSES

Thorough technical analysis and comprehensive environmental impact reporting are important parts of a successful groundwater banking program and also crucial components in winning public support. In addition, the perception that implementation steps are being taken before technical studies are completed can undermine public confidence in the project before it even starts.

Technical analyses were a major point of contention in the Madera Ranch groundwater banking project. The technical analyses performed by the U.S. Bureau of Reclamation were preliminary in nature and designed to assist the USBR in making decisions regarding the feasibility of the project. However, project opponents considered the studies to be superficial and flawed. They believed that the feasibility of the proposed project was not demonstrated sufficiently for policymakers to commit public funds to the project and characterized the USBR's decision to proceed as "getting the cart before the horse." Particularly, they were concerned that the banked water would interact with surface streams and migrate from the site, creating root zone flooding problems for neighboring orchards and other sensitive crops,[9] and that extractions from the bank would come at the expense of neighboring wells due to the failure to account for the lost water. Although the quality of the technical analyses was not necessarily the primary problem with the State Drought Water Bank project, the programmatic environmental impact report (PEIR) prepared by DWR in 1993 was not convincing to local stakeholders. A common view in Butte County is that the PEIR was not very useful. It offered only general predictions of the nature and magnitude of potential impacts of the program. As is typical of programmatic reviews, site- or project-specific impacts were not addressed. Mitigation measures for groundwater overdraft or impacts on surface water flows were neither identified nor adopted.

In contrast, the EBMUD project is considered to be technically strong, illustrating that technical merit, while important, is not the only factor necessary to garner local support or ensure project success.

TIME CONSTRAINTS

While not always controllable, compressed timeframes for project development can impair a project. When the development is rushed, it is less likely that local stakeholders will be involved adequately to "buy into" the project, which is especially important in regions without a strong history of support for conjunctive management. Shortened timeframes also can lead to inadequate technical analysis. For instance, had the Madera Ranch project continued into a second phase of investigation, the technical analysis would have addressed several outstanding issues in more detail. It appears that the landowner-imposed deadline for USBR action to commit to the project, or acquire the project site, lent impetus to move ahead without the benefit of more definitive technical studies or significant local involvement. Some feel that the property owner's deadline for USBR action forced a premature commitment by USBR that would have been avoided given a longer timeline.

PLANNING AND RESPONSE TO DROUGHT

Drought conditions can provide the impetus for local agencies to engage in groundwater banking. In the case of the Kern Water Bank, the formation of the Future Water Supply Committee, an important first step that led to the establishment of the Bank, was spurred on by the prolonged drought from 1987 to 1992, which resulted in significant impacts to water users in Kern County. However, projects primarily created as emergency responses to drought conditions rather than deliberately designed water resource projects can encounter significant problems if they are extended. For example, the State Drought Water Bank in Butte County functioned well from 1991 to 1992, when it was created in response to drought conditions. However, in 1994 it foundered, at least partly due to the increased pumping associated with the extraction phase of groundwater banking. In Butte County, many wells were too shallow to operate in the drawdown conditions caused by the drought and the combined pumping of the water bank on top of the agricultural extractions. These wells went dry, causing financial impacts on local users and fostering local opposition to the project.

A lesson from this experience is that counties and their local groundwater management entities would do well to set up "stand by" drought water banking arrangements well in advance of the next period of extended drought. Prior to a drought or other emergency, these authorities could design a program with a specified range of extraction rates, tied to various hydrologic conditions, that would avoid well interference. With adequate lead time, the technical analyses needed to set these rate could proceed deliberately with ample public review. After the required EIR and related analyses have undergone adequate review, the local agency could approve the terms for the operation of the groundwater bank in advance of the need to actually implement the program. Then, when a drought condition or other circumstance arises that requires a relatively quick response, the "stand by" plan will have received all necessary approvals and permits. Two key ingredients for the success of such an anticipatory plan would be adequate hydrogeologic understanding of the aquifer and an appropriate monitoring system already in place. This approach would require significant initial investment from the water sellers. However, given the value of a reliable supplemental source of groundwater in times of statewide need, some form of funding to subsidize establishment of such a system would seem an investment worth evaluating.

MONITORING PROGRAMS

Monitoring programs are important to winning local support. Accurate and extensive monitoring programs can ease landowners' concerns over the potential that the groundwater bank will extract native groundwater in addition to the banked water (more "take" than "put") and thus diminish their supply. Monitoring programs can also lead to improved understanding of basin stratigraphy and recharge mechanisms and may therefore help prevent groundwater bank operation problems such as those that occurred in the 1994 State Drought Water Bank. One area of strong consensus within Butte County and DWR is that the monitoring network in Butte County should be expanded prior to future conjunctive use projects. They believe that additional dedicated monitoring wells are needed in locations currently being identified through hydrogeologic investigations. A related need is to improve public access to the monitoring data. One proposal is to make continuously recorded water levels and pumping rates available in real-time over the Internet.

INSTITUTIONAL ARRANGEMENTS AND LOCAL CONTROL

The cases teach that local interests view groundwater projects more favorably when they are locally controlled. And, it is common for local groundwater users to worry that a proposed groundwater export project could present a means for outside interests to gain access to native groundwater and, potentially, surface water entitlements. This fear seems to persist irrespective of the actual or proposed terms of the contract, probably as a result of the “water grab” from the Owens Valley in the 1920s. There is also fear that reliance on aquifer storage by a municipal water agency might eventually be codified by the legislature. These are fears that may not be well founded, but they are genuine. In general, local interests must be assured that the potential third party impacts are mitigated before a project can move forward.

In both the EBMUD and Madera Ranch projects, fear of losing local control over groundwater supplies presented a considerable obstacle to the successful implementation of the project. In the EBMUD example, while the pilot project was technically sound, fear of an outside entity gaining control of San Joaquin County groundwater supplies enmeshed the project in political controversy. Overlying landowners were concerned that the project represented a means for a municipal water supply agency to "stick a straw" into the local aquifer and to become reliant on the water supplied by the banking operation, eventually leading to the loss of their water rights. Even with the protections provided by the amended County ordinance in place, local interests still feared the encroachment of outside agencies into the Eastern San Joaquin Groundwater Basin.

The EBMUD example is not unique in that the issues of local control of groundwater and the protection of overlying landowner rights are a common theme in the San Joaquin Valley as well as other areas. In the Madera Ranch project as well, issues of local control were a major factor in local opposition to the project.

There are several potential antidotes to the fear that local control will be lost. As on this writing, some nineteen counties have passed groundwater export ordinances that generally prohibit exports in the absence of a permit of limited duration, issued by a local groundwater management authority. Water Code Section 1016, added in 1999 to address the specific concern that groundwater transfers can exceed contractual term limits, now removes any legal basis for that concern. However, contractual limitations on the duration of a water supply may be more appealing than statutory limitations because a breach of contract would give rise to a right to compensation for damages. Concerns over local control can also be addressed through contracts that cede control over project operations to local authorities. In the Madera Ranch case, for example, an agreement could have been negotiated with the county to establish a stakeholder monitoring committee and set up enforceable operational rules for the project. This, coupled with an agreement to provide a quantity of banked water to alleviate conditions of overdraft, might have decreased concerns over loss of local control. Notably, such measures were successful in garnering local support in the Kern Water Bank.

Local Support and Public Involvement

As one commentator noted: "a public interaction program, or the lack thereof, is often the sole or major reason for the failure to implement a water program."[10] Establishing and maintaining early, continuous, and two-way communications between the public, stakeholders and the water agency, preferably starting on "day one" of the project, is an essential element for a successful program and for building consensus. [11, 12] Local opposition was the factor that had perhaps the most significant impact on all three of the unsuccessful projects. These projects show that local support is crucial to the success of groundwater banking projects and that substantial opposition at the local level can "sink" a project even when its technical merits are strong. In the 1994 State Drought Water Bank example, there is a general consensus within Butte County that the DWR Bank "managers" were not well connected with the local communities that the project impacted. Based on earlier success in 1991 and 1992, the 1994 bank clearly did not anticipate the problems that arose, nor did it effectively address the complaints of third parties who were, or perceived they were, adversely affected. While the local DWR office in Red Bluff dealt with citizen complaints about increasing impacts of pumping on third parties, the bank managers were not in regular communication with the staff of that office. The 1994 experience demonstrated to DWR staff the need for public education and involvement in the process of developing and implementing groundwater banking projects. Following the problems experienced in the summer of 1994, a few workshops and public meetings were conducted by local DWR staff in Butte County.

In the example of Madera Ranch, local opposition is cited as the major factor in the USBR's decision to abandon the project. [13, 14] The USBR undertook what it saw as a logical response to the landowner's proposal by performing a preliminary analysis of potential "fatal flaws." However, local stakeholders felt that USBR should have consulted with them about the project at the conceptual stage and utilized local knowledge of geography, aquifer response, and historic water levels during the preliminary investigation. Local concerns that the project was "top-down" and driven by political rather than technical considerations were reinforced when the project was prematurely championed in several political arenas before technical studies were completed. In the EBMUD project, local opposition was very strong and centered around the fear of an outside entity gaining control of groundwater in San Joaquin County.

Making the process open and transparent by keeping all information "on the table" to the extent possible (outside of privileged negotiations) is also important for gaining public trust. One complaint of the local opponents of the Madera Ranch groundwater banking project was that this did not occur in that case.

OUTSTANDING ISSUES

The case studies illuminate many of the institutional design factors that produce successful results. However, several design issues remain due to uncertainties in the state of the law governing groundwater rights in California. These uncertainties translate into risks to the operation of conjunctive use projects that could be ameliorated by legislative clarifications. The legislative recommendations at the end of this section are specifically intended to facilitate actively recharged groundwater banking projects as described earlier in this document, but would be beneficial to conjunctive use projects in general.

Among the needlessly problematic legal uncertainties is the demarcation of regulatory authority over the recharge and extraction of water banked in aquifers. At present, several types of entities with different procedural and regulatory requirements may assert jurisdiction and vie for control. In cases where the legislature has unambiguously vested management authority over specific groundwater resources in a special district, the competing jurisdictional claims are probably quieted.[15] However, this circumstance is rare. Typically, the jurisdictional boundaries are unsettled and unsettling.

Unless the banked surface water is held under a pre-1914 appropriative right, the project likely must obtain a "change order" from the State Water Resources Control Board (State Board), authorizing the transfer from a surface source to the groundwater bank.[16] To obtain such an order, the proponent of a conjunctive management project bears the burden of establishing, before commencing the project, that the recharge and withdrawal of water will not adversely affect other legal users of water.[17] Commonly, impacts that would otherwise constitute legally cognizable injury may be mitigated or avoided through implementation of a "physical solution," which may be incorporated into the project design or imposed by the State Water Resources Control Board or a court.[18] Such change orders generally must comply with the California Environmental Quality Act, which requires that changes in groundwater tables and their effects be disclosed, assessed and mitigated. Yet, the project may also have to comply with regulatory requirements imposed by a local groundwater management authority or a permitting authority created by county ordinance. The local bodies may assert jurisdiction at both the importation and storage stage and at the extraction stage and generally impose their own version of a "no injury" rule. The potential for conflicting or overlapping standards, procedures and requirements is obvious.

Uncertainty as to the division of regulatory jurisdiction is compounded by a degree of uncertainty as to proprietary rights among: (1) the importer of the recharge water; (2) the overlying landowner(s); and (3) the overlying water district. Additionally, the application of area of origin protections to the re-export of imported recharge water has not been decided.[19] Lastly, whatever the rights and remedies, enforcement problems haunt groundwater banking to the same extent as other groundwater entitlements.

In the discussion below, we approach the legal issues from two vantage points: (1) who has proprietary rights and (2) who has regulatory authority over the exercise of those rights.

Proprietary Rights to Imported Water

With respect to proprietary rights, it is important to clarify that, in the case of actively recharged groundwater banks, we are not concerned with native or *in situ* groundwater, to which the overlying landowners presumptively enjoy correlative possessory rights. In the case of imported water,[20] the case law seems clear that the recharged water belongs to the importer, less whatever losses may occur.[21] A water right holder who imports the water with the purpose of later extracting it has the paramount right to extract that water for use either on the overlying lands or on remote locations,[22] subject of course to the requirement of avoiding injury to legal users of the native groundwater with which the imported groundwater may commingle. Injury could arise, for instance, where extraction wells are located proximate to those of pre-existing groundwater users and where the rate of extraction creates a cone of depression that increases the neighbor's pumping power requirements compared to pre-existing conditions. Calculating the amount of water to which the importer is entitled to withdraw, however, is challenging. Equally difficult is enforcing one's rights to imported water against unauthorized withdrawals by other users of the aquifer.

Another complication arises around who has the paramount claim to augmented groundwater recharge as a consequence of reoperation of upstream reservoirs. Stated another way, the question is: when the operations of a reservoir are changed to release additional amounts of water to the stream channel, some of which percolates into the downstream aquifer system, is this recharge water to be considered "imported" water that would not have been available but for the act of reoperating the reservoir? In that event, it would seem to belong to the reservoir operator. Or is this water natural recharge that would have been available to the overlying groundwater users but for the pre-existing operations of that reservoir, and therefore belongs to those groundwater users?[23]

In the main, however, the critical uncertainties are not over who owns the imported water, but over how that ownership right can be enforced where there are numerous overlying groundwater rights holders whose respective rights to pump from the aquifer have not been determined.

Property Interests in Aquifer Storage Space

As a practical necessity, groundwater banking must be developed with the cooperation and consent of overlying landowners, water districts or groundwater management authorities. As we have noted previously, there is no realistic prospect of some outside entity imposing a groundwater bank on unwilling local interests. However, where there is local opposition to a locally initiated project, the issue arises as to who owns and controls the dewatered storage space in an aquifer and who has the right to utilize that space or to exclude others from doing so.[24] It is likely that the courts would regard the storage space in an aquifer as a shared asset that all overlying landowners have a correlative right to use but that such rights holders may neither exclude other overlying landowners from using the aquifer storage space nor exact a "rental fee" for such use.[25]

Rather than characterizing the issue as one of trespass on a property interest, it may be more workable to regard it as just another application of the "no injury" rule. Thus, the correlative rights holders might well be legally entitled to prevent a water banking project from reducing the natural infiltration capacity of the aquifer. These results seem likely because the California Supreme Court has already held that public agencies can store water in aquifers.[26] The Court, analogizing groundwater banking to a surface water reservoir, deems this an economical and efficient method of "natural storage," only subject to the limitation that storage and withdrawal does not harm other legal users by, for instance, interfering with natural recharge. In the case of such interference, imported water is deemed to "spill first" after the aquifer becomes fully recharged.[27]

Under this view, the real issue is not "who owns the storage space" but how does one calculate the amount of water that the importer is entitled to withdraw. The basic theory behind the importer's exclusive right is that the water would not be there at all but for the act of importation. But where the importation supplants natural recharge or increases leakage from the aquifer, the basic theory does not justify giving the importer any right at all, let alone an exclusive right. However, it would obviously be helpful for the legislature to make clear that groundwater users do not have an ownership interest in unoccupied aquifer storage space beneath their property.

Tort-based decisional rules may serve well to protect landowners from physical injuries or water supply impacts associated with groundwater banking, but the courts may need to revert to property based rules to apportion unsaturated aquifer storage space among overlying landowners competing to bank imported surface water. In the usual case, these overliers will be seeking to operate recharge and recovery facilities under contract with a non-overlying end-user such as a municipality. Several potential allocation formulas could be applied: (1) correlative rights to storage under which, like the right to exploit native groundwater, each overlying landowner has an equal right to access and utilize the aquifer storage space subject to mutual avoidance of harm and subject to the paramount right of other overliers to the natural recharge of that aquifer; (2) equitable apportionment of aquifer storage considering populations served by the banked water, investments in effecting it, etc.; (3) "first in time is first in right", analogizing to the appropriative rights doctrine to encourage and reward initiative to create groundwater banks. There are no known precedents to suggest how, ultimately, these aquifer apportionment issues will be resolved.

Restricting Groundwater Users to Historic Usage

Whether pre-existing groundwater users can be restricted to historic levels of usage to assure that they are not taking imported water that has been banked in the same aquifer is a contentious issue.[28] The general rule is that, subject to the avoidance of mutual harm, groundwater users are entitled to as much groundwater as they can beneficially use as long as the "safe yield" of the aquifer is not exceeded. This is true irrespective of their historic usage. If their historic use is less than their correlative share of the safe yield or the amount available for appropriation under their priority of right, restricting these users to their historic usage arguably diminishes their legal entitlement.

However, the problem may be more apparent than real. Groundwater banking programs are most likely to be established in two circumstances: (1) where there is a pronounced pre-existing cone of depression that can be filled (i.e. the San Joaquin Valley) or (2) where aquifers are already full such that groundwater will have to be extracted first in order to create storage space (i.e. the Sacramento Valley). In the first instance, the aquifer is already in overdraft. Current users are not entitled to increase their pumping because that would necessarily injure other rights holders.[29] In the second case, increased pumping by historic users is unlikely to adversely affect other users, including the groundwater banking project, because the aquifer has plenty of water in it.

The problem is also less likely to arise in areas of groundwater use that are incorporated within a water district, even those that do not regulate groundwater. Where a water district operates a groundwater bank within its service area, such as the Semitropic Water Storage District, Kern Water Bank or Arvin-Edison Water Storage District projects, it does so with the consent and support of those members who rely on groundwater.[30]

In the intermediate case—where the basin is close to balance and the groundwater bank is in an unincorporated area—the appropriate principle would seem to be that existing uses can be allowed to increase only to the level that would represent safe yield, absent the groundwater bank, but no further. The problem in applying that principle is the difficulty in establishing the safe yield level short of adjudicating the basin. Even in the relatively rare circumstances where these conditions prevail, groundwater banking may be practical without adjudication if the bank can tolerate some increase in groundwater pumping or can purchase forbearance from pumping increases from existing groundwater users.

Who Has Regulatory Authority Over Groundwater Banks?

State Water Resources Control Board

The issue here is whether the State Water Resources Control Board enjoys continuing jurisdiction over imported surface water stored in groundwater basins, and if so, the extent of its regulatory authority.[31] The State Board clearly has jurisdiction over the source water if it is subject to an appropriative permit, i.e., if the appropriation occurred after 1914. If the State Board receives a petition to change the place and manner of use of that water so that it can be banked in an aquifer and then extracted for ultimate use on non-overlying lands, does the State Board retain jurisdiction over each link in this chain, including the process of recharge and recovery? Or does the imported water lose its character as surface water when it becomes commingled with the native groundwater, thereby precluding further regulatory supervision by the State Board?

Though no state board opinions are directly on point, continuing limited State Board jurisdiction over surface water placed into underground storage can be inferred from various permits issued over the last fifty years. Initial research shows that, in a limited number of cases, the State Board has issued permits and change orders to store surface water underground. These permits and change orders specify both the place of underground storage as well as the beneficial use to which the water will ultimately be put when it is subsequently diverted out of storage.[32] And, once the Board approves underground storage of surface water, several State Board decisions and water rights orders[33] make clear that the State Board retains jurisdiction to ensure that the water is ultimately used beneficially and reasonably.[34] The State Board's jurisdiction stems from its permitting authority over the original diversion from a natural watercourse, and its control extends to not only the diversion but also to the subsequent use.[35] The State Board decisions seem to treat surface water placed into groundwater storage as if it were still surface water, subject to the reasonableness and public trust limitations which the Board places on all permitted water rights.

While the State Board does have jurisdiction, the important issue is how that authority interfaces with the powers asserted by local groundwater management entities. That issue is treated on the next page.

Local Groundwater Agencies

Assembly Bill 3030[36] permits existing water agencies to create groundwater management districts. However, the authority that AB 3030 confers on districts is limited to determining safe yield, imposing modest restrictions on withdrawals, replenishing supplies, and imposing fees and assessments on extractions. The districts are not authorized to make binding determinations on matters related to water rights. Nor are AB 3030 districts authorized to prevent the exportation of groundwater. The authority to limit or suspend extractions may only be exercised if the district determines that replenishment programs or alternative water supplies are infeasible or inadequate.[37]

There are ten specially enacted groundwater management districts[38] and several other local agencies with groundwater management authority.[39] The powers of these districts and agencies are varied, and a few require a permit for withdrawal or export of groundwater.

CITY AND COUNTY REGULATION

Cities and counties possess the power to regulate groundwater[40] except to the extent that such ordinances conflict with specific state legislation.[41] There has been a great increase in the number of counties passing groundwater management ordinances, especially in the last few years.[42] The ordinances vary greatly in terms of purpose (e.g., monitoring, replenishment, export restriction) and type of restriction (e.g., permit compliance, impact analysis, fees). Most of the ordinances require a permit to export groundwater outside of the county or to extract groundwater *in lieu* of surface water use. Few of them distinguish between native groundwater and imported water.[43] Some do explicitly recognize the value of conjunctive management and provide an exception to the permit requirement where it is demonstrated that the activity will result in net annual recharge.[44]

The Potential for Conflict Between State and Local Jurisdictions

As noted above, the State Water Resources Control Board asserts jurisdiction over permitted surface water that is temporarily stored underground, essentially treating it like surface storage. Counties also assert jurisdiction over water that is temporarily banked in their local aquifers, generally through ordinances creating groundwater planning and permitting authorities. Demarcating the division of regulatory labor between these levels of government in advance would help demystify groundwater banking and reduce the regulatory risk factors.

Jurisdiction could be shared sequentially or concurrently. In a groundwater banking operation, the water moves through a series of discrete steps: from a surface water source, through a conveyance channel (which may be a natural channel), to a recharge facility, to an aquifer, through a recovery well, through a conveyance facility (which, again, may be a natural channel), and finally to a point of ultimate beneficial use. Through each link in this chain, the banking operation has the potential to affect other water rights or cause injury to other legal uses of water, including instream beneficial uses. If the source water is subject to permit, clearly the State Board has jurisdiction over its appropriation and use. Is there then some point in the "life history" of that water at which the State Board loses its jurisdiction, or does the it retain jurisdiction to the point of ultimate consumptive use or outflow from the system? Some water lawyers believe that, when the imported water is commingled with native groundwater, State Board jurisdiction ceases. However, we have not been able to find any precedent or other legal support for this view. Moreover, it is not apparent why surface water stored underground should be treated any differently than water stored in a surface reservoir for purposes of the State's administration of water rights.

There is, however, a compelling practical limit to the State Board's ability to regulate groundwater recharge and recovery operations. While it may well be that the State Board could act to protect native groundwater users from the effects of a groundwater banking operation, it could not apparently act to protect the banker from the other groundwater users. This is because it does not have jurisdiction over the latter. This asymmetry may render its nominal authority in the aquifer ineffectual in a practical sense.[45]

If, not withstanding this asymmetry, jurisdiction is to be shared concurrently, then it would seem that the State Board pre-empts or supplants local regulation of the stored groundwater only to the extent of actual conflict. This raises the question whether the local authorities are able to go beyond the State Board's extent of jurisdiction or only beyond its scope of jurisdiction. In other words, may the local jurisdiction prescribe measures that are more protective of the other "legal uses of water" or is it restricted to protecting against types of injury not covered by State Board regulation, such as impacts to structures or crops from rising water tables? Under the latter approach, county regulation that substantially affects the definition or exercise of water rights, especially post-1914 appropriative rights, is likely to be preempted. For instance, the State Board's determination as to the volume or rate of banked water that can be extracted without adverse consequence to users of native groundwater would preclude contrary determinations by the local jurisdiction.

Area of Origin Statutes

The application of area of origin protections to the re-export of imported recharge water has not been decided but likely does not pose an impediment to groundwater banking.[46] California Water Code Section 1220[47] prohibits the export of groundwater from the "combined Sacramento and Delta-Central Sierra basin" unless the pumping is in compliance with a groundwater management plan approved by the county board of supervisors and subsequently approved by popular vote. The statute does not distinguish native groundwater from imported, foreign water, notwithstanding that imported water transferred into groundwater storage under a permit issued by the State Board can readily be distinguished from native groundwater. Since the statute's apparent intent is to apply area of origin protections to groundwater, the courts will probably limit its application to exports of native groundwater, not imported recharge water.

Recovering Water Banked Through "In Lieu" Arrangements

Under an *in lieu* arrangement, the groundwater banking authority would enter into arrangements with overlying landowners who already use groundwater for all or a portion of their supply and also have access to surface water deliveries. During periods when the banker desires to recharge groundwater, the overlying landowners would forego pumping and accept a substitute surface delivery instead. The aquifer recharges passively from natural infiltration and percolation of the applied surface water. When the program desires to extract groundwater, the landowner would curtail its surface water use and substitute groundwater pumping. The mass balance in the groundwater basin is the same whether the water is actively recharged or delivered *in lieu* of groundwater pumping. In both cases, during years of storage, more water is contained within the basin than would have been stored absent the program. Ideally, arrangements should also be made with other groundwater users not participating in the *in lieu* recharge, such as appropriators, to minimize the risk that non-participants will take "banked" water and to provide relief in the event the banking operation injures a non-participant's water rights.[48]

In lieu banking projects differ from active recharge projects in that the groundwater that they extract is not water that the project has physically put into the aquifer. Instead, *in lieu* projects require groundwater rights holders in some years to forego pumping water that they are otherwise legally entitled to extract and to offset that forbearance by drawing more heavily on the aquifer in other years. Notwithstanding this operational difference, California Water Code sections 1005.2 and 1005.4 treat *in lieu* projects as equivalent to actively recharged projects with respect to the right to extract the groundwater that becomes available as a result of the program.[49] As is the case with active recharge, there are problems of enforcement and accounting. In years of forbearance, the other pumpers might extract the water that the program intended to store. In years of extraction, the contracting landowner's rates of withdrawal may harm correlative pumpers.

Of course, the problem associated with *in lieu* recharge may be avoided where groundwater basins have been adjudicated and the particular extraction rights have been quantified. This is the situation with a number of groundwater basins in Southern California. The great drawback of adjudication is the time and cost associated with the process. In non-adjudicated basins where rights have not been quantified, contractual arrangements among all or most basin users may provide sufficient reliability to assure that a banking entity can recover the banked water.

Recommended Resolution of Issues

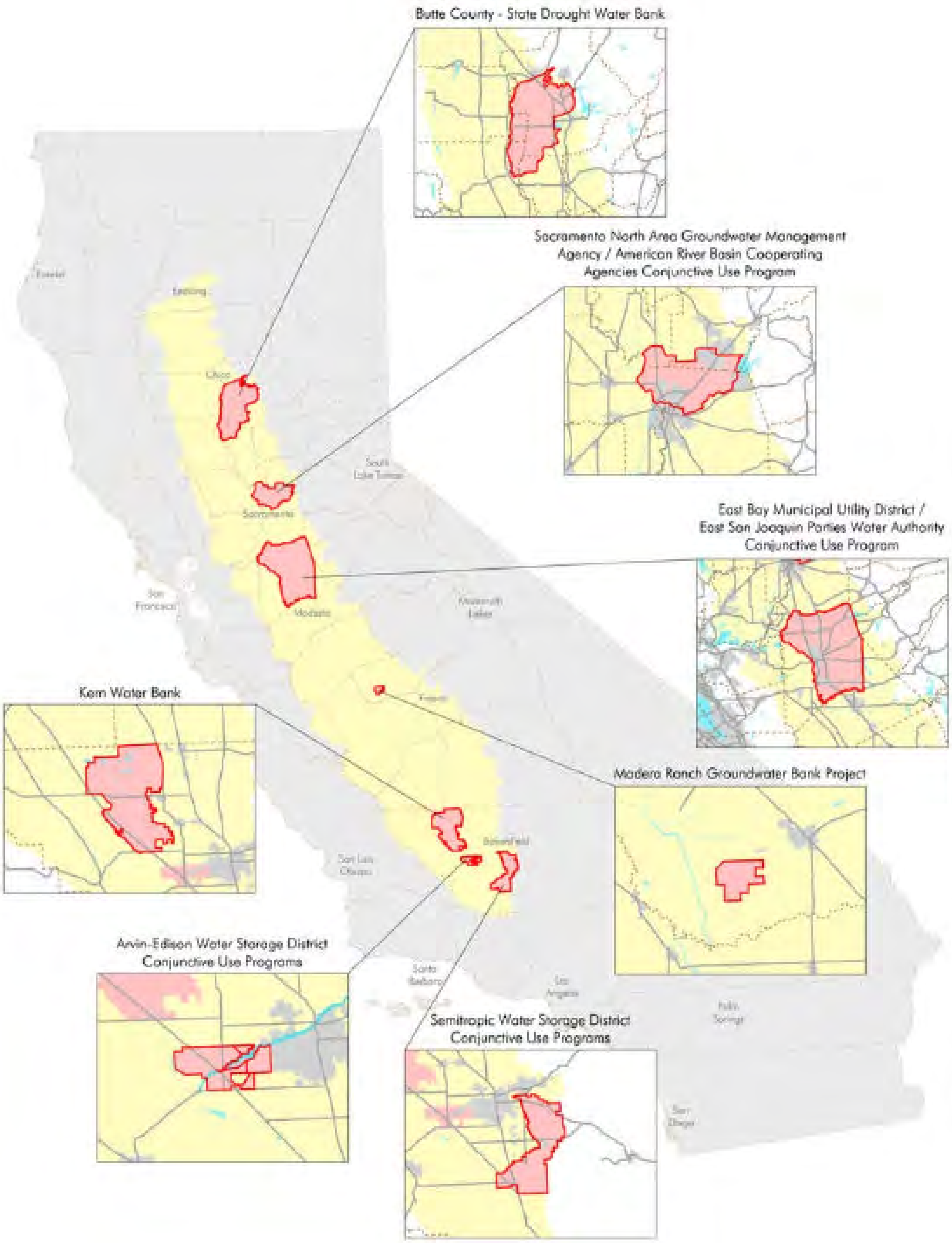
Improved hydrogeologic baseline information, including information on the depths of existing wells, would greatly assist in devising successful conjunctive use projects and in ameliorating local concerns. DWR’s update of its groundwater report, Bulletin 118, now mandated by the legislature, is not detailed enough to serve as the vehicle. Use of Proposition 204 and Proposition 13 funds should be investigated for this purpose. If this is not an eligible use of funds, the Legislature should consider substantial additional appropriations for this specific purpose.

The State Board should convene a process involving its staff and outside experts to develop principles and guidelines for such key terms as "injury," "safe yield," "baseline conditions," "basin," "imported water," etc.

The following clarifications in California groundwater law would markedly facilitate groundwater banking while increasing the protection for other groundwater users. The legislature should consider codifying these clarifications:

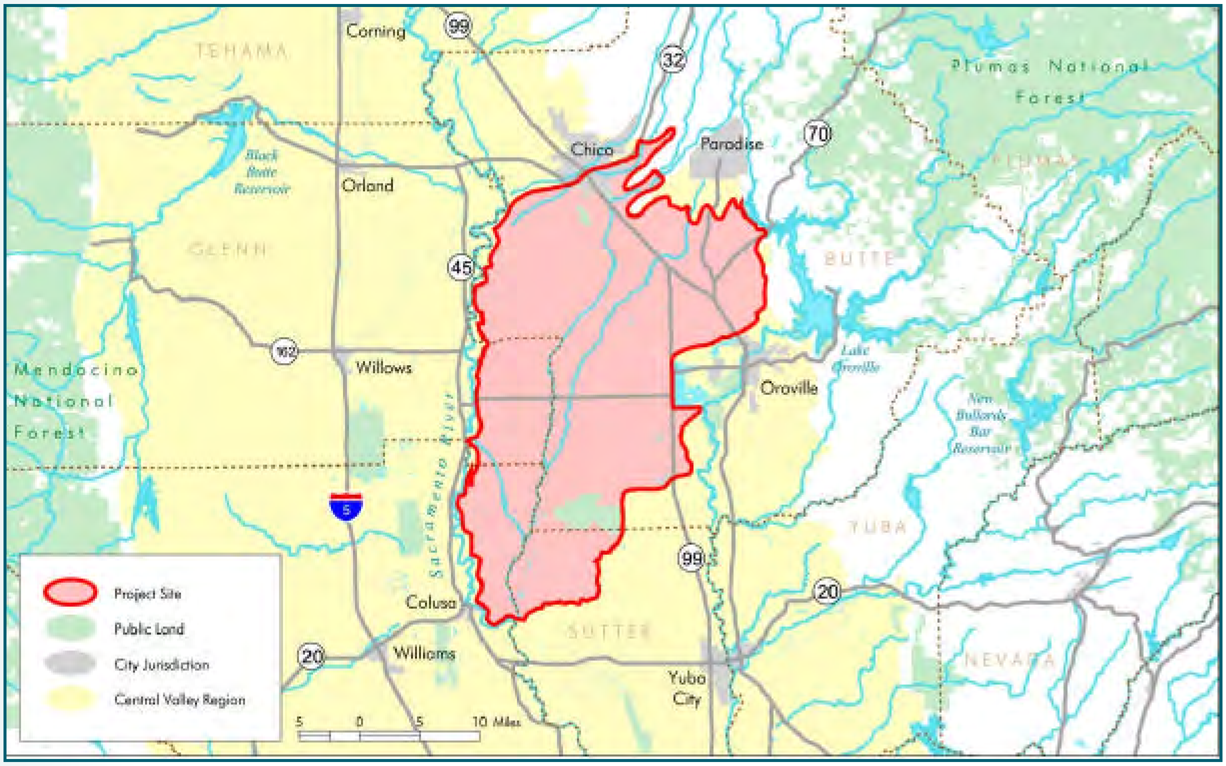
- Overlying landowners have correlative rights to the groundwater but do not have a right to exclude other overliers from utilizing the unsaturated aquifer storage space, although such overlying landowners are entitled to compensation for any injury to crops, lands or structures resulting from the recharge of the aquifer by others.
- Unless it initiates an action to adjudicate the entire groundwater basin, a banker of imported water may not enjoin historic levels of use of groundwater on overlying lands. However, the banker retains the right to protect banked water from net increases in extractions by the pre-existing groundwater users, beyond that historic baseline, in aquifers that are in an overdrafted condition. The groundwater banker would have to first proceed against groundwater appropriators, if any.
- A legal user of water may not enjoin a groundwater banking project that offers to provide a "physical solution" to such legal user, whether or not that offer is accepted, provided that the appropriate regulatory authority or court finds that the physical solution would have constituted adequate mitigation.
- The State Water Resources Control Board retains jurisdiction over surface water (subject to post-1914 appropriative rights) that is stored in groundwater basins and pre-empts conflicting requirements imposed by county ordinance that significantly affect or redefine water rights or legally cognizable injury.
- County ordinances and local groundwater management authorities may not restrict recovery and re-export of "foreign" water imported into the groundwater basins, except to the extent necessary to prevent injury to other legal users of the groundwater basin, as that principle is understood under existing law.

The Case Studies



Map above shows the locations of the seven conjunctive use projects studied in this report

BUTTE COUNTY — STATE DROUGHT WATER BANK



Introduction

On February 1, 1991, after four years of drought in California, and facing a fifth year of below-average precipitation, Governor Wilson initiated the State Drought Water Bank (SDWB) to meet anticipated critical water needs. This case study reviews the 1991, 1992, and 1994 State Drought Water Bank programs in the Butte Basin, in which local water districts were paid to relinquish deliveries out of Oroville Reservoir and substitute groundwater instead. The relinquished surface water was then available for delivery to drought victims south of Sutter County (primarily State Water Project [SWP] contractors south of the delta and in the San Francisco Bay Area). Therefore, within the Butte Basin, the SDWB operated as a groundwater substitution project. While the 1991 and 1992 SDWB programs are generally considered successes, the 1994 SDWB generated considerable controversy within Butte County. Coupled with an additional year of intense drought, elevated SDWB pumping was perceived as having adversely affected local wells. Details of specific program years are discussed below.

Physical Characteristics

PHYSICAL AND ENVIRONMENTAL SETTING

The geopolitical area of study is Butte County, located in the northeastern Sacramento Valley. Butte Basin, the primary groundwater basin, lies within western Butte County, the southern portion of Tehama County, the northern portions of Sutter and Colusa Counties, and the eastern portion of Glenn County. The Butte Basin has traditionally been defined as bounded on the west by the Sacramento River, on the east by the foothills of the Sierra Nevada, to the north by Pine and Singer Creeks, and to the south by the Sutter Buttes and the Yuba River.[50] Land use in the region is predominantly agricultural, and large volumes of surface and groundwater are dedicated to producing rice, walnuts, almonds, prunes, wheat, and row crops. Urban water demand is approximately 10% of the total water use.[51] A list of the major water delivery systems, both agricultural and municipal, is presented in Table 5.1 below.

Table 1

WATER SERVICE DISTRICTS AND AREAS IN BUTTE COUNTY/BUTTE BASIN

Note: Districts shown in italics participated in sales to the 1994 SDWB.

AGRICULTURAL WATER SERVICE DISTRICT	CITY / MUNICIPAL WATER SERVICE AREAS
M&T Ranch Inc.	Chico
Durham Municipal Water Company	Durham
Parrott Investment Company (Llano Seco)	Oroville
Western Canal Water District	Biggs
Richvale Irrigation District	Gridley
Reclamation District 1004	Live Oak
Biggs-West Gridley Water District	Yuba City
Butte Water District	Marysville
Sutter-Extension Water District	
Thermalito Irrigation District	
Oroville-Wyandotte Irrigation District	
Browns Valley Irrigation District	
Rameriz Water District	
Cordua Irrigation District	
Hallwood Irrigation Company	

HYDROLOGY

The climate of the region is Mediterranean with cool, wet winters and hot, dry summers and little to no rainfall. Unpublished precipitation records suggest that, in three out of ten years, the Butte Basin area experiences precipitation that is significantly less than the long-term average rainfall. Precipitation shows strong orographic patterns with the foothills receiving over twice the precipitation of the Sacramento Valley floor (greater than 50 inches versus approximately 25 inches, respectively).

Surface water runoff entering the Butte Basin is dominated by the spring snowmelt period. High magnitude rainfall in the late fall and early winter, or during infrequent rain-on-snow events, can also generate peak flows in regional creeks and rivers.[52] At present, the Butte Basin aquifer system is described as being full or nearly full during years of normal or above normal precipitation (i.e., the average annual recharge appears to be sufficient to replenish local groundwater use). Drought conditions, especially over multiple years, cause water levels to decline until normal or above-normal precipitation years resume. Overdraft within the basin does not appear to be occurring based on long-term groundwater well hydrographs maintained by the Department of Water Resources (DWR). There is a perception among individuals interviewed for this study that overdraft may be occurring in the Chico area due to increasing urban demand. The DWR staff with the Groundwater Section at the Northern District Office in Red Bluff has recently re-evaluated Chico area groundwater level data. They found an average water level decline of approximately 12 feet for the period

1978–2000, accounting for periods of drought and subsequent recovery. Water levels appear to have stabilized since the end of the 1994 drought. Rather than evidence of overdraft, these data have been interpreted as evidence that the groundwater system has responded to increased pumping stresses with declining water levels but appears to be reaching a new equilibrium.

Project History

The State Drought Water Bank was initiated in early 1991 after four years of drought. Water was made available to the 1991 Bank by curtailing surface water deliveries to water districts in Butte County so that this water could be delivered to SWP contracting districts south of the delta. In 1991 and 1992, irrigation districts within the Butte Basin had their surface water allocations reduced by 375,000 acre-feet each year to meet emergency statewide needs, as permitted by delivery contracts. Butte County farmers were paid for water they made available by improving irrigation efficiency, reusing tailwater, fallowing agricultural fields, or substituting groundwater for relinquished surface water. During the 1991 program period, approximately 10,000 acre-feet of groundwater was pumped directly for export. Groundwater substitution pumping in 1991 totaled 62,000 acre-feet, with approximately 33,000 acre-feet produced by the Western Canal Water District and approximately 29,000 acre-feet produced by the four districts of the Joint Water Districts Board. Pumping rates, timing and locations were such that parties relying on groundwater for domestic, agricultural or municipal uses noticed no significant adverse impacts. Most of the public in Butte County apparently was unaware that the SDWB program was underway.

The Butte County/Basin districts that increased groundwater pumping during the 1991 State Drought Water Bank included: Western Canal Water District, the Joint Water Districts Board (Richvale Irrigation District, Biggs-West Gridley Water District, Butte Water District, and Sutter Extension Water District) Ramirez Water District, Cordua Irrigation District, Hallwood Irrigation Company, and Browns Valley Irrigation District. Participants in the 1994 State Drought Water Bank were Richvale Irrigation District, Western Canal Water District, Browns Valley Irrigation District, Cordua Irrigation District, and Ramirez Water District.

Below-average precipitation continued during 1992, prompting DWR to establish a second SDWB program. The 1992 Bank generally followed the model of the 1991 Bank, except that fallowing was discontinued (as was also the case in 1994) because it was perceived to have undesirable economic and social impacts. Drought conditions in 1992 were less severe, and thus the SDWB transactions were the smallest of the three years of SDWB operation. The consensus within Butte County appears to be that the 1991 and 1992 SDWB programs were successful statewide responses to real emergencies.

After an average precipitation year in 1993, severe drought conditions returned in 1994, leading to the most recent and controversial SDWB program. Based on the apparent success of the 1991 and 1992 SDWB programs, five local water districts (Western Canal, Richvale, Browns Valley, Ramirez, and Cordua) elected to participate in water sales to the 1994 SDWB. Three of the districts (Browns Valley, Ramirez, and Cordua) are quite small and third party groundwater users did not experience adverse impacts from SDWB pumping by these districts. The other two Butte Basin water sellers (Western Canal Water District and Richvale Irrigation District) increased their groundwater substitution pumping to approximately 100,000 acre-feet in 1994 to help meet statewide needs.

Western Canal Water District and Richvale Irrigation District entered into contracts with

DWR on behalf of individual district members intending to act as willing sellers to the Bank. These contracts prescribed the volume of groundwater that could be substituted for relinquished surface water deliveries. For example, the Western Canal Water District contract set pricing of substituted groundwater at $50 per acre-foot up to a maximum of 90,000 acre-feet. Water was sold to DWR, which in turn entered into water sales contracts with willing buyers. The contracts between the districts and DWR specified that SDWB activities would not invalidate any existing water rights. CEQA responsibilities were assigned to DWR but were addressed through a Programmatic Environmental Impact Report (PEIR) as described below. Liability for damages arising from pumping was retained by DWR. The sellers, not DWR, retained control of the timing and rate of pumping itself. This proved to be problematic during the 1994 SDWB because, although DWR retained liability for pumping and water level related impacts, the Department could not readily suspend pumping if problems arose.

Several factors contributed to the problems encountered in 1994. First, very low precipitation during the spring forced farmers to initiate irrigation earlier than normal to flood rice fields and support orchard demands, thus significantly increasing groundwater pumping. Second, spring surface runoff reduced recharge to the local aquifer system, which had already been depleted by the previous multi-year drought.

The magnitude and location of pumping by Western Canal and Richvale near the eastern boundary of the Butte Basin, combined with higher than average pumping by others, reduced groundwater levels to the point that, by July 1994, some nearby domestic and agricultural wells were adversely affected. During the summer of 1994, water levels in wells not participating in the SDWB declined such that several domestic wells failed to produce water. Some wells reportedly sustained pump damage, while others had to be deepened. A complicating factor is that many agricultural groundwater users primarily pump on weekends, when electrical rates are the lowest. This tended to temporally concentrate pumping stresses and may have contributed to depressed water levels in some areas.

In July 1994, third party complaints prompted a temporary cessation in pumping by the SDWB at selected wells. It is important to stress, however, that the problems that occurred in 1994 likely resulted from the combination of drought history, SDWB pumping, and agricultural pumping practices. Groundwater level monitoring data did not conclusively point to SDWB pumping as a unique source of the problems, and thus pumping was resumed in some wells. However, the majority of the SDWB wells adjacent to the Cherokee Strip were turned off until the second week in August. Individuals who experienced pumping-related problems began to coalesce in ad hoc groups and later in organized forums such as the Valley Water Protection Association.

Subsequent to the 1994 SDWB program, the State of California began development of a Supplemental Water Purchase Program. The intent of the program was to develop a more systematic approach to future groundwater management in relation to droughts and water transfers. Initial groundwater substitution production targets were approximately 400,000 acre-feet. A draft EIR was issued by DWR in 1996, but opposition by local interests in the Sacramento Valley was sufficient to cause DWR to reduce the groundwater substitution goals to 200,000 acre-feet. The CEQA process has never been completed, and the original Supplemental Water Purchase Program is viewed as having been superseded by the CALFED process. Opposition continues to statewide or regional groundwater pumping targets developed in the absence of local planning.

SDWB PARTICIPANTS

The 1991 SDWB, like subsequent programs in 1992 and 1994, relied on willing surface water users to forego portions of their entitlements so that the project could deliver that water to buyers south of the delta and in the San Francisco Bay Area whose normal supplies were constrained by the drought. DWR operated the SDWB, including identifying willing buyers and sellers and serving as the "broker" for the water transfers. DWR entered into contracts for both the purchase of water from the selling water districts and for the resale of that water to the buyers. The selling water districts obtained the water through contracts with willing sellers (district members) and then managed the pumping regime.

DWR identified potential sellers to the 1991 Bank through the State Water Contractors. In 1994, the SDWB was well established and likely sellers were already known. Buyers for the 1994 SDWB were primarily agricultural users (93% of sales). In Butte County, local water users sold but did not buy water from the Bank. Individual users within the water districts elected to pump groundwater as a substitute for surface water that was transferred through the Feather River or other surface water conveyances.

BENEFICIARIES

From a financial perspective, the individuals who sold water to the Banks and those who purchased water from it were the primary beneficiaries. Sellers who benefited may be presumed, in most instances, to have used proceeds from water sales to invest in their farm operations or buy goods and services in the local communities. However, the benefits to the local water users in Butte County were uneven. Some water districts were better equipped with production wells than others, and, thus, the ability of districts to participate in the program was highly variable. Likewise, within districts that did participate, some individuals had the wells and/or financial resources to increase pumping capacity, while others did not. Groundwater users not participating in the SDWB programs received no benefits from the program.

As a result of the SDWB programs, buyers in urban areas were able to minimize impacts on landscaping and reduce the need for emergency water conservation measures. Agricultural buyers were able to protect orchards and other permanent crops and minimize potential layoffs of farm employees. Environmental benefits also accrued from the increased instream flows to maintain fisheries and to protect water quality in the Delta. One environmental benefit that is not widely recognized within Butte County was a significant contribution of SDWB proceeds to fund a $9 million siphon project on Butte Creek aimed at improving local salmon populations. In addition, the County received 2% of the gross proceeds from groundwater sales to help fund development of a Butte Basin Groundwater Model.

STAKEHOLDER PARTICIPATION

Throughout all three SDWB programs, DWR viewed the water sellers and the districts that represented them as the stakeholders of concern. These water sellers organized the Butte Basin Water Users Association (BBWUA) in 1992. This group became the point of contact with DWR technical staff and Butte County staff who had little direct involvement in the Bank activities beyond monitoring the SDWB process itself.

PUBLIC PARTICIPATION

While the public was not excluded from the SDWB process, little evidence exists of efforts to actively involve local communities or third parties who rely on groundwater but were not involved in groundwater substitution pumping. During 1991 and 1992, such public participation was viewed as unnecessary, but the 1994 experience demonstrated a need for the public to be educated and involved. Following the problems experienced in the summer of 1994, local DWR staff from the Red Bluff office conducted a few workshops and public meetings in Butte County.

Environmental Review

The 1991 and 1992 banks were one-year emergency programs, and as such were exempted from CEQA compliance. Environmental reviews were conducted when preparing the individual water sale contracts, but no formal CEQA documents were prepared for the overall SDWB program prior to 1993.

A programmatic environmental impact report (PEIR) was prepared by DWR in 1993 to address potential impacts of the SDWB. However, a common view in Butte County is that the PEIR was not very useful. It offered only general predictions of the nature and magnitude of potential impacts of the program. As is typical of programmatic reviews, site or project-specific impacts were not addressed. Mitigation measures for groundwater overdraft or impacts on surface water flows were neither identified nor adopted. With the data collected since 1993 and better predictive methodology, it seems likely that creating new EIRs for conjunctive use projects would be more useful than attempting to update the 1993 document.

Technical Studies

To date, the only comprehensive technical study of groundwater use in the county has been through the development of a groundwater management computer model for the Butte Basin. In 1992, the BBWUA retained a private consultant, Hydrologic Consultants, Inc., to develop the model in order to aid future water management. Hydrologic data from a variety of agency and water district sources was compiled for use in the simulations. Grid-scales employed in the model are on the scale of miles, and thus the model cannot simulate third-party impacts at individual well locations. Rather, the model is intended to aid in basin-scale analyses and planning. The Red Bluff office of DWR conducts studies of countywide land and water use every five years. Additionally, there have been a variety of geologic, hydrologic, and soils investigations conducted by various agencies and universities.

Monitoring Program

Since the inception of the SDWB programs, DWR, Butte County, and the Western Canal Water District have monitored groundwater conditions systematically. Approximately eighty to ninety wells have been monitored for groundwater levels on a quarterly basis. However, only about ten of the wells are solely for monitoring and not also used for production. Some additional monitoring wells have been added through investigations at the M&T Ranch towards the northern end of the Butte Basin. There is a strong consensus within Butte County and DWR that more monitoring is needed to prevent recurrence of the problems experienced in 1994. All believe that additional dedicated monitoring wells are needed in locations currently being identified through hydrogeologic investigations. A related need is to improve public access to the monitoring data. One proposal is to make continuously recorded water levels and pumping rates available in real-time over the Internet.

Financial Characteristics

Costs of the SDWB Program

The costs of operating the SDWB programs were recovered through the difference between the buying and selling prices. In 1991, water was purchased at $125 per acre-foot and was sold at $175 per acre-foot. Approximately 37 percent of the water purchased in 1991 was surplus to the demand that year and was carried over to the following year.[53] During the 1992 and 1994 Banks, water was purchased for $50 per acre-foot and sold for $72.50 per acre-foot. Reductions in the price offered by DWR to sellers and adjustments in the timing of commitments to sell and buy allowed the 1992 and 1994 banks to be more efficient so that they accumulated less surplus water.

Issues and Risks

HYDROGEOLOGIC RISKS

One of the significant challenges to future conjunctive use projects in Butte County and elsewhere in the Sacramento Valley stems from the fact that a significant number of wells are relatively shallow. DWR estimates that there are approximately 5500 domestic wells with 50% reaching depths less than 135 feet.[54] It is unlikely that these wells can function reliably with large drawdowns during drought conditions. Thus, it may be difficult to conduct groundwater substitution projects without substantial investments in deepening a large number of wells. Given the ad hoc nature of the SDWB programs compared with other strategic conjunctive use projects, there have been no systematic analyses of pumping thresholds required to prevent or avoid third-party impacts similar to the ones experienced in 1994. Pumping volumes were specified in contracts as a range, but the upper and lower limits were not based on detailed knowledge of local groundwater systems or the potential for third party impacts.

ENVIRONMENTAL RISKS

Currently, a wide variety of efforts are underway to protect and restore riparian ecosystems. One of the recent concerns raised about future groundwater substitution projects is the potential for adverse impacts on riparian vegetation and certain oak species that are reliant on adequate deep soil moisture associated with ambient water table levels. Very little is known about the potential impacts of lowering regional groundwater levels on sensitive vegetation communities. If managed groundwater level fluctuations occurring in future conjunctive use projects were shown to be adversely affecting local riparian systems, it is likely that some form of administrative or legal intervention could occur.

LEGAL RISKS

Based on its success in 1991 and 1992, the 1994 Bank clearly did not anticipate the problems that arose, nor did it effectively address the complaints of third parties who were, or perceived that they were, adversely affected by its operations. Third parties interviewed for this case study cite a period following the end of the 1994 SDWB program when neither DWR nor participants in the SDWB pumping would acknowledge that impacts occurred. This seems to have been due to the fact that the possibility of damage occurring to third parties was not seriously considered during development of the SDWB. Affected third-parties contracted with a consulting firm to identify SDWB pumping impacts. Following that study, dialogue between DWR staff and the consultant failed to resolve different interpretations as to whether SDWB pumping caused adverse impacts to third party wells. At that point, a group of affected third parties retained a law firm to explore the prospects of successful litigation for SDWB-related damages. Estimates of legal fees reached approximately $500,000, which was beyond the financial resources of the parties involved. However, given the increase in community involvement since the last SDWB, several organizations and individuals have threatened litigation if the problems of 1994 recur.

Subsequently, DWR established a process to evaluate claims of damages resulting from Bank-related pumping. DWR, and in many instances the water district where SDWB pumping occurred, reviewed claims and groundwater data for evidence of third-party impacts.

Where claims were substantiated, DWR offered monetary settlements, most of which covered the increased power costs for pumping from greater depths. These compensation efforts were generally viewed as insufficient to compensate third parties, and the entire claims process remains a source of dissatisfaction and distrust among some of the interviewees. The countywide consensus is that every effort should be made to avoid a repeat of the 1994 conflicts.

Other Third Party Impacts and Community Relations

Following the 1994 SDWB, Butte County placed a short-term moratorium on new wells in mid-1994. Opposition from the water districts coupled with potential impacts on agriculture and new residential development caused the moratorium to be lifted by late 1994. Seeking another solution, the County developed and circulated a concept paper that explored local controls on groundwater management. Local water districts reportedly opposed the language—if not the concept—and this effort was also discontinued.

A group of individuals that experienced third party impacts formed in 1996 to seek local legislation via a ballot initiative (Measure F) to protect groundwater resources and users. Several weeks later, local water users and participants in the SDWB programs placed an alternative groundwater management initiative (Measure G) on the ballot. It was apparently difficult for many voters to distinguish differences between the competing measures. Supported by significantly greater campaign funding, Measure G was approved by the voters in November 1996. Prior to Measure G, there was no program to manage water issues at the County level. The most significant elements of Measure G, codified as Chapter 33 of the County Codes, include establishment of a permit process for approving water sales in future SDWB or related programs; a County Water Commission with support from a Technical Advisory Committee; and administrative staff to follow water issues. The Commission and staff are in place, but no individual or district has applied for a water sale permit to date. Details of the application process are still being refined.

Local stakeholders hold divergent views regarding progress in implementing Chapter 33 {Measure G}. One person contacted in this study commented, "this Measure was born in crisis and remains in crisis." Some perceive implementation as a slow but steady process. In July 1999, the County formed a Department of Water and Resource Conservation. The Water Commission and the new Department are working to implement Chapter 33, mainly through the development of small workgroups representing various interests. More recently, Butte County has entered into a Memorandum of Understanding with DWR to examine local options under the Integrated Storage Investigation (ISI) program. The ISI program is designed to support locally initiated and controlled conjunctive use programs that will contribute to statewide water supplies under both drought and non-drought conditions. A local ISI stakeholders group has been formed with representatives from all sectors of the community actively participating in local water issues.

In general, the current process is viewed as a significant improvement over the situation prior to 1996. Policy questions are being debated in a more open manner and with substantial public participation. Virtually all of the individuals contacted who are involved in water sales feel the Water Commission adequately represents the County’s interests. In contrast, individuals who rely solely on groundwater sources see the need for greater representation of third parties on the Commission.

Several potential problems in the water permitting process have been identified. For example, the time frame to complete a permit under optimal conditions (no legal challenges) is estimated to be about nine months. This may conflict with the time period between a drought declaration on February 15 and the onset of peak water demands in the spring (approximately 4 months). However, if the permit processing time is reduced, the time available for citizens concerned about potential third-party impacts to comment would also be reduced. Observers agree that the Measure G permit process cannot be accurately evaluated until the first permit application creates a test case.

Conclusions

Comparing the activities of the SDWB programs in 1991, 1992 and 1994 to other conjunctive use programs in California is very difficult in that the three programs were primarily emergency responses rather than deliberately designed water resource projects. When problems arose in 1994, the SDWB program was unable to respond in an effective manner. Accordingly, the current implementation of Chapter 33 (Measure G) may be viewed as the first process in Butte County for designing conjunctive use projects.

The problems experienced during the 1994 SDWB program exposed several core issues that must be addressed in future groundwater management and conjunctive use projects. These issues may be grouped into two general areas: (1) monitoring of basin surface and subsurface hydrology and (2) planning and decision-making processes.

Efforts to evaluate 1994 pumping impacts were seriously impeded by insufficient knowledge of local groundwater systems and an inadequate network or monitoring wells. There is a consensus among interviewees that the monitoring network in Butte County should be expanded prior to future conjunctive use projects. Despite the existence of substantial groundwater level data in the Butte Basin, there is general agreement that a detailed understanding of the structure of the aquifer system is still lacking. The local U.S. Geological Survey Hydrologic Atlas[55] describes the Sacramento Valley as a single undifferentiated groundwater basin unit. Current investigations by the Northern District of DWR suggest that a much more complex pattern of distinct aquifers and recharge areas may exist. The type and spatial distribution of recharge mechanisms needs to be thoroughly investigated as future conjunctive use planning proceeds. Improved understanding of Butte Basin stratigraphy and recharge mechanisms may significantly contribute to preventing a recurrence of the problems encountered in the 1994 SDWB.

Changes in the planning and decision-making processes seem to be of equal or greater importance. As previously noted, the planning that occurred in the SDWB programs was essentially an emergency response. Subsequent attempts to develop groundwater management and water transfer programs[56,57] have been unsuccessful due to intense local opposition in the Sacramento Valley in general and Butte County in particular. Local acceptance and control appears to be critical to any stable conjunctive use planning program.

From the interviews, it seems that third parties (non-SDWB pumpers) carried and still seem to carry the burden of proving that pumping impacts occurred in 1994. Unfortunately, given the passage of time and the limitations on knowledge of the aquifer system described above, the magnitude and spatial distribution of SDWB impacts on third-party groundwater levels may never be known definitively. One possible resolution of this issue is to shift the responsibility for identifying pumping-related impacts from third parties to future conjunctive use projects themselves. Prospects for such a change in Butte County appear promising.

Significant efforts have been made to create a more open framework for future conjunctive use planning and decision-making in the region. Virtually all interest groups in Butte County recognize that the state government is likely to impose measures on the County in response to future emergencies if a local planning framework does not evolve soon. While there is general interest in finding an acceptable approach, much work remains to be done to fully implement Chapter 33. To create an optimal project planning and review process, local and state interests will need to commit adequate funding and other forms of support this implementation work. Some specific changes that have been recommended for the current planning and decision making processes are listed below. The first water sale permit application under Chapter 33 will be a vital test of the durability of the willingness of local stakeholders to work together.

The County should consider adopting a template for evaluating future conjunctive use projects and/or water sales. This might allow an individual or water district to obtain pre-approval of a proposed groundwater pumping rate prior to actually implementing a drought banking scheme. After any required environmental review and related analyses, the County could then approve the proposal which would be implemented when and if the need were to arise. Approval might require that the proponent present an adequate characterization of the aquifer system and have appropriate monitoring program already in place. This approach would require significant initial investment from the water sellers. Given the value of a reliable supplemental source of water in times of statewide need, some form of funding to subsidize establishment of such a system would seem an investment worth evaluating.

Summary of recommendations proposed by interviewees to improve planning for future conjunctive use projects

LEGAL ASSURANCES

- Liability for damages resulting from conjunctive use projects should be clearly defined.
- A trust fund or escrow account should be established to ensure timely compensation in the event of third party impacts on groundwater pumpers not involved in the water sale.

HYDROLOGIC ASSURANCES

- Specific thresholds of impacts that would trigger a cessation of pumping need to be set in more definitive terms than those specified in Measure G.
- Water sale permits should require that drawdowns created by groundwater substitution pumping be confined to within the project or water district boundaries.
- An emergency pumping shutoff procedure is a critical need and must be established.
- Initial conjunctive use projects should emphasize locations where delineation of sub-basins or specific aquifer zones that are sufficiently characterized to determine acceptable drawdown limits.

IMPROVEMENTS IN THE PLANNING PROCESS

- Mitigation measures necessitated by conjunctive use projects or related water transfers should be reviewed in the planning process.

- The County should review the composition of the Water Commission to improve its representation of diverse interest groups.
- The basin management objectives approach being pursued in Glenn County should be employed in Butte County.

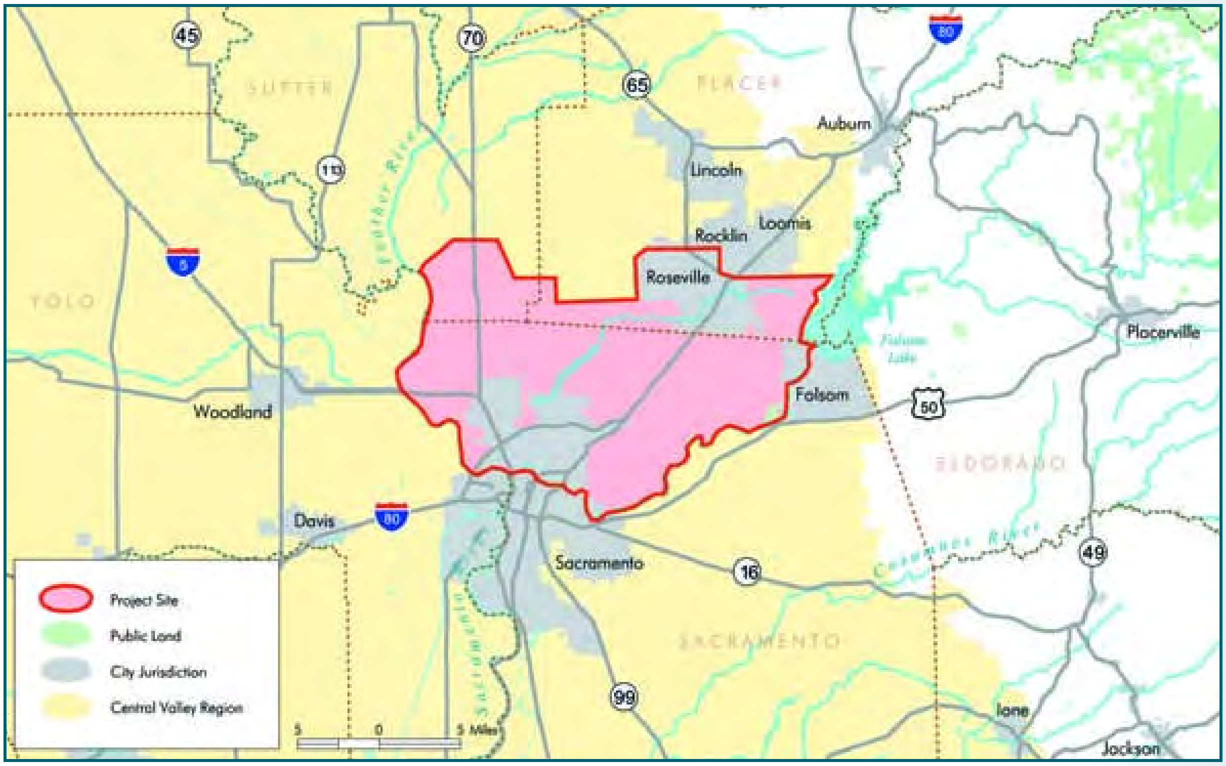
IMPROVEMENTS IN THE PERMITTING PROCESS

- The time frame for water sale permits must be streamlined, but adequate time for EIR review must also be provided.
- Water sales approved by the Water Commission should require five "aye" votes out of the nine members rather than a majority of a quorum present.
- The overall permit process needs to be made more understandable to the public.

IMPROVEMENTS IN THE MONITORING PROCESS

- Monitoring data must be made available to all interested public and private parties in an expedited manner.
- Cumulative effects of multiple water sale permits must be evaluated and monitored.

SACRAMENTO NORTH AREA GROUNDWATER MANAGEMENT AGENCY
AMERICAN RIVER BASIN COOPERATING AGENCIES
CONJUNCTIVE USE PROGRAM



Introduction

This case study reviews the conjunctive use program proposed by the Sacramento North Area Groundwater Management Authority (SNAGMA) and the American River Basin Cooperating Agencies (ARBCA). The Sacramento North Area Conjunctive Use Program illustrates how interest-based negotiations can lead to consensus on regional water issues and formulation of regional water plans. While a full-scale conjunctive use project for the north area of Sacramento has not yet been implemented, a regional conjunctive use program is currently being planned in collaboration with a broad range of stakeholders. SNAGMA and ARBCA, as well as other collaborators, have expended significant time and effort in order to build consensus for a regional water plan. Their efforts have been based largely on the Sacramento Water Forum process and the resultant Water Forum Agreement.

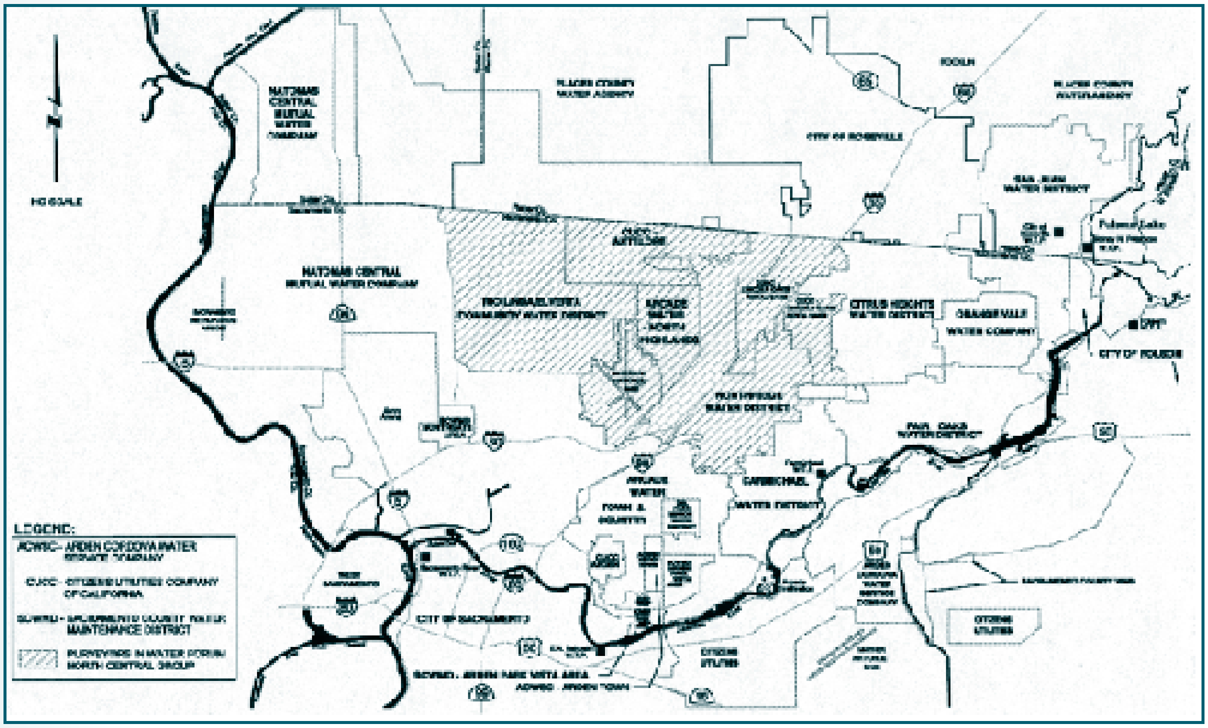
Physical Characteristics

SETTING

The proposed Sacramento North Area Conjunctive Use Program falls inside the northern portion of the Sacramento Groundwater Basin, which is located within the southern portion of the Sacramento River Hydrologic Region. Northern Sacramento County and southern Placer County overlie the potential project area, which is bounded on the north by the Placer County Water Agency, on the south by the American River, on the west by the Sacramento River, and on the east by the Sierra Foothills, (see figure 1 on the following page). While much of the overlying area is urbanized, significant agricultural activities still exist in western areas of Sacramento and Placer counties. The political jurisdictions and water purveyors within the proposed project boundaries include the following:[58]

- Arcade Water District
- Carmichael Water District
- Citizens Water Resources
- Citrus Heights Water District
- City of Folsom
- City of Roseville
- City of Sacramento
- County of Sacramento
- Del Paso Manor Water District
- Fair Oaks Water District
- Natomas Mutual Water Company
- Northridge Water District
- Orange Vale Water Company
- Placer County Water Agency
- Rio Linda/Elverta Community Water District
- Southern California Water Company
- San Juan Water District

AMERICAN RIVER BASIN COOPERATING AGENCIES / REGIONAL WATER MASTER PLAN
Figure 1



HYDROLOGY

Current water demand in the proposed project area is approximately 320,000 acre-feet per year. Approximately sixty percent of water demand is met with surface water, while forty percent is met with groundwater. Water usage can be characterized as approximately eighty percent municipal and industrial, fifteen percent agricultural, and five percent "self-supplied" via groundwater.[59] Groundwater pumping in the area, mostly for municipal and industrial uses, averages 125,000–130,000 acre-feet per year. Overdraft is estimated to have created 1 .5 million acre-feet of available storage (i.e., de-watered aquifer capacity), with a cone of depression centered in the vicinity of McClellan Air Force Base.[60,61,62] Approximately 400,000 to 600,000 acre-feet of the de-watered aquifer space is assumed to be useable for recharge.

Primary sources of surface water in the area include Folsom Lake, the American River, and Sacramento River. Nearly 900,000 acre-feet of surface water is available to agencies in the proposed project area pursuant to pre-1914 water rights, other appropriative water rights, Central Valley Project (CVP) contract entitlements, and settlement agreements.[63] The Sacramento metropolitan area is the largest urban area within the Sacramento River Hydrologic Region and is the largest urban user of surface water. The largest city within the Sacramento metropolitan area, the City of Sacramento, meets the water needs of its 400,000 residents with a mix of eighty percent surface water and twenty percent groundwater (approximately 100,000 acre-feet per year surface water and 22,000 acre-feet per year groundwater).

Available aquifer storage space, the potential for making use of excess surface water flows, and the combination of public agencies and investor-owned water purveyors that use both surface and groundwater create the necessary pre-conditions for a regional conjunctive use program in the Sacramento area.

Project History

Over its eight year history, the Sacramento Water Forum has evolved from a city-county effort into a program with buy-in from a broad range of regional stakeholders. Using a process of interest-based negotiations, the Water Forum has had several successes including the development of: SNAGMA, a regional water master plan, a water action plan agreement, an EIR, a joint-powers authority for the management of groundwater, a cooperative organization for the implementation of conjunctive use projects and the analysis of potential conjunctive use projects.

The following brief history of the Sacramento North Area Conjunctive Use Program outlines several of the most important processes that have led the Program to where it is today.

THE SACRAMENTO WATER FORUM

The Sacramento City-County Office of Metropolitan Water Planning (CCOMWP) was formed in October 1991 for the purpose of conducting regional water planning for the Sacramento area. The mission of the CCOMWP was to develop a regional water plan to address development and environmental needs in Sacramento through the year 2030. Initially, the CCOMWP conducted water demand analyses and groundwater modeling. Efforts expanded to include input from twenty-two Sacramento area water purveyors and the community at large. A stakeholder-driven process to develop a water action plan was initiated when the CCOMWP convened meetings with a variety of stakeholders including water purveyors, representatives of the business community and representatives from development, environmental, and agricultural interest groups.[64]

Out of this stakeholder-driven process, the Sacramento Water Forum (Water Forum) was formed in 1993. The Water Forum is an ongoing water planning effort that has been cited as an outstanding example of how a collaborative process can be used to develop a regional water plan and cooperative projects. Its mission is to develop and implement a plan to meet two coequal objectives: (1) to provide a safe and reliable water supply for the region's economic health and planned development through the year 2030 and (2) to preserve the fishery, wildlife, recreational, and aesthetic values of the lower American River.[65] After six years of research and negotiation among the stakeholder groups, the members of the Water Forum signed an agreement and action plan to meet the coequal objectives. The agreement and action plan seek to avoid future water shortages, environmental degradation, groundwater contamination, threats to groundwater reliability, and limits to economic prosperity.

For the purposes of this study, the key element of the Water Forum Agreement is the one dealing with groundwater management. This element provides the basis for the formulation of the Sacramento North Area Groundwater Management Authority (SNAGMA, adopted in August 1998), the American River Basin Cooperating Agencies (ARBCA), and the Sacramento North Area Conjunctive Use Program.

SNAGMA

The Sacramento groundwater basin consists of three sub-basins—the North Area, South Area, and Galt Area—each with its own unique conditions and problems.[66] The Water Forum Groundwater Management Element recommends an annual sustainable yield for each sub-basin. In the case of the North Area, the recommended sustainable yield is 131,000 acre-feet per year, a figure based on the volume extracted in 1990.[67]

The North Area is bounded by the American River on the south, the Sacramento County line on the north, the Sacramento River on the west, and the City of Folsom on the east. The Water Forum Groundwater Management Element recommended that the North Area move ahead with groundwater management under a Joint Powers Authority (JPA) form of governance structure. This decision was based on the following four factors:[68]

- The North Area is closer to build-out than the other two areas;
- Delivery systems for surface water are already being expanded and utilized to a greater extent in the North Area;
- Organized purveyors serve almost all of the North Area, including agriculture. Thus, the institutional infrastructure necessary to implement groundwater management is further developed in the North Area; and
- The Sacramento Metropolitan Water Authority, which includes eight of the twelve water purveyors in the North Area, wishes to implement a groundwater management plan as soon as possible and has already taken action to do so.

Pursuant to the Water Forum recommendation, a Joint Powers Agreement that uses the existing authority of the Cities of Citrus Heights, Folsom, Sacramento, and County of Sacramento established the Sacramento North Area Groundwater Management Authority (SNAGMA).[69] SNAGMA boundaries are coincident with those of the North Area Basin. The JPA requires the participation, through its Governing Board, of representatives of the County of Sacramento, the cities, private and public water purveyors, investor-held utilities, and groundwater rights holders in the North Area. Additionally, the SNAGMA Governing Board includes representatives of agriculture and commercial/industrial self-supplied (groundwater) users within the JPA boundaries.[70] The membership of the SNAGMA Governing Board consists of representatives from the boards or councils of the following North Area agencies, water purveyors, and stakeholders:

- Arcade Water District
- Carmichael Water District
- Citrus Heights Water District

- Del Paso Manor Water District
- Fair Oaks Water District
- Northridge Water District
- Rio Linda/Elverta Community Water District
- San Juan Water District
- City of Folsom
- City of Sacramento
- Sacramento County Water Maintenance District
- Southern California Water Company
- Citizens Water Resources
- Natomas Mutual Water Company
- Orange Vale Water Company
- Agricultural representative
- Self-supplied representative

SNAGMA is responsible for a wide variety of groundwater management functions in the North Area, including: collection and monitoring of groundwater data; maintenance of the recommended sustainable yield; and development and administration of a conjunctive use program. Additionally, SNAGMA is authorized to do the following:[71] (See next page).

Buy and sell water on other than a retail basis;

Exchange water, distribute water for ceasing, or reducing, groundwater extractions;

Spread, sink, and inject water into the North Area Basin;

Store, transport, recapture, recycle, purify, treat, or otherwise manage and control water for the beneficial use of persons and property within the authority;

Implement any conjunctive use program the Authority deems necessary to maintain sustainable yields in the North Area;

Study and plan ways to implement any or all of the foregoing powers;

Store water in underground basins or reservoirs within or outside of the Authority;

Exercise the right of eminent domain to take property necessary to supply the Authority with replenishment water;

Levy taxes, fees, or charges to accomplish the purposes of the Authority;

Require permitting of groundwater extraction facilities within the boundaries of the authority and meters for groundwater extraction facilities;

Carry out technical investigations to further the purposes of the Authority;

Set rates at which water acquired by the Authority can be sold for replenishment purposes;

Participate in *in lieu* contracts; and

Apply for and accept state, federal, or local licenses, permits, grants, loans, or aid.

Cited as one of the first authorities of its kind in California, SNAGMA provides an example of how collaborative negotiation processes can supply a structure for local control of groundwater resources. As seen from the list of SNAGMA's responsibilities and the number of participants, the Authority is a consolidation of local interests that have delegated their powers to it for the purposes of collectively managing groundwater resources.

ARBCA and the Regional Water Master Plan

While SNAGMA's role is primarily one of groundwater management, American River Basin Cooperating Agencies (ARBCA) was formed for the broader purpose of creating a regional partnership for water resources planning and conjunctive use project implementation.[72] ARBCA is funding the development of a Regional Water Master Plan (Regional Plan), estimating the cost of infrastructure needed for implementing a regional conjunctive use program, and developing operating agreements and institutional arrangements for conjunctive use, water banking and exchange.[73] The objectives of the Regional Plan are to enhance water supply reliability, provide high quality water and protect economic interests, while allowing each water purveyor to make its own business and policy decisions.[74]

ARBCA consists of water purveyors from Sacramento County, the City of Roseville, and Placer County Water Agency.[75] The total membership of Cooperating Agencies consists of the following:[76]

- Arcade Water District
- Carmichael Water District
- Citizens Water Resources
- Citrus Heights Water District
- City of Folsom
- City of Roseville
- County of Sacramento
- Del Paso Manor Water District
- Fair Oaks Water District
- Northridge Water District
- Placer County Water District
- Rio Linda/Elverta Community Water District
- San Juan Water District
- Southern California Water Company

In addition to the Cooperating Agencies, there are six Collaborating Agencies participating in the ARBCA regional water master planning and conjunctive use effort. These are:

- California Department of Water Resources (DWR)
- Natomas Mutual Water Company
- Orange Vale Water Company
- Sacramento Metropolitan Water Authority
- SNAGMA
- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation

In particular, the Bureau of Reclamation and DWR have provided assistance in the form of grant funding and in-kind services. ARBCA and SNAGMA have formed a partnership for the purposes of developing and coordinating the Regional Plan and implementing a conjunctive use program. The goals and objectives of ARBCA and SNAGMA are fully compatible and the significant membership overlap simplifies facilitation of the partnership. SNAGMA's role in the partnership is to establish the contractual arrangements needed to implement the conjunctive use program per the Regional Plan, exercise its authority to manage the groundwater basin, and provide the legal and political certainty for entering into long-term water banking and water exchange agreements.[77]

The ARBCA Cooperating Agencies are bound together by a series of Memorandums of Understanding (MOUs) that commit each agency to fund their share of the Regional Plan.[78] ARBCA has also established an organizational structure to oversee the development of the plan. An executive committee, consisting of technical experts and policy makers representing each member agency, provides direction and guidance. A coordinating committee, composed of a subset of the executive committee, oversees consultant team activities and develops meeting agendas. Finally, an implementation options committee evaluates institutional and policy issues that could impact the implementation of the Regional Plan. The San Juan Water District acts as the financial agent of ARBCA, as directed by the executive committee.

The development of the Regional Plan is proceeding in the following three phases:[79]

> Phase I — develop common goals and objectives for the implementation of conjunctive use, establish the current setting (supplies, demands, existing facilities), identify potential conjunctive use opportunities, and prepare a Phase II scope of work for evaluating water management and conjunctive use opportunities. Phase I was completed in June 1999.
>
> Phase II — configure the opportunities identified in Phase I into a Regional Plan institutional framework with specific projects identified and studied. Phase II includes the development of Integrated Groundwater and Surfacewater Model and economic and financial models and a communications strategy. Phase II is anticipated to be complete by April 2001.
>
> Phase III — develop draft agreements, conduct an environmental review of the Regional Plan and implement the conjunctive use program.

Groundwater Banking Opportunities

The ARBCA/SNAGMA partnership is exploring ways to establish a North Area Conjunctive Use Program to satisfy the Groundwater Element of the Water Forum Agreement. The partnership is developing a groundwater banking and exchange program that will take advantage of the regional cone of depression in the Sacramento area and integrate the operation of Folsom Lake with the recharge of the groundwater basin. Several options that have been proposed are described below.

The concept holds that, during a banking cycle, or "put" operation, surface water diversions from the American and/or Sacramento Rivers would be stored in the groundwater aquifer underlying the North Area and southern Placer County. The banking could occur either as *in lieu* recharge or direct recharge via spreading or injection. During the exchange cycle, or "take" operations, the banked groundwater would be extracted for local use *in lieu* of surface water diversions. Thus, surface water could be left in reservoirs for temperature control for fisheries, recreational uses or for releases to satisfy a variety of other purposes.[80]

To test the potential of the concept and the strength of institutional arrangements, the ARBCA/SNAGMA partnership conducted a pilot program to use conjunctive water management for water supplies to the Sacramento Area Flood Control Agency (SAFCA) on an on-call basis. Implemented with the participation of ARBCA/SNAGMA, SAFCA, and the U.S. Bureau of Reclamation (USBR), the program allows SAFCA to divert and bank water in the basin during wet months. Exchange water is available for SAFCA to satisfy its refill obligation associated with flood pool reservation in Folsom Lake.

Under the pilot program, banking is accomplished by diversion of raw water from Folsom Reservoir and treatment at San Juan Water District Water Treatment Plant. Treated water is wheeled through the Cooperative Transmission Pipeline and the Northridge Water District Transmission Pipeline for banking via *in lieu* groundwater recharge. In the exchange cycle, Citrus Heights Water District extracts groundwater in an amount equal to the banked water, foregoing a portion of the treated water normally supplied to the city by San Juan Water District. This frees an equal amount of water that San Juan Water District can then make available to SAFCA. San Juan Water District then foregoes portions of its diversions from Folsom Reservoir to make water available to SAFCA.[81]

The ARBCA/SNAGMA pilot program has been successfully implemented, and the partnership is now pursuing an expanded banking and exchange program with the CALFED Environmental Water Account (EWA). The pilot program serves as a good test of the institutional capabilities to bank and exchange water and is indicative of the willingness of the regional partners to move forward with the full-scale Sacramento North Area Conjunctive Use Program.

Institutional Arrangements

PROJECT TIME FRAME

The proposed Sacramento North Area Conjunctive Use Program is on a four to five year schedule, based on the Regional Water Master Plan timeline (1998 to beyond 2000). However, as stated previously, the Program actually has it roots in the 1991 CCOMWP formation, progressed through six years of Water Forum negotiations, and is now in the ARBCA/SNAGMA regional planning phase. Thus, the timeframe for development of the Sacramento North Area Conjunctive Use Program could be viewed as extending over ten years or more.

PARTICIPANTS

See list of Cooperating and Collaborating Agencies involved in the ARBCA Regional Water Master Plan formulation above.

BENEFICIARIES

Project beneficiaries include the participating agencies listed above as well as the environmental and business interests represented by SNAGMA. Essentially, a variety of stakeholders across the entire region benefits from the conjunctive use program.

PROJECT OPPOSITION

At the Water Forum stage, there was some opposition by regional environmental interests because of recommendations for increased diversions. These issues were resolved through the interest-based negotiation process.[82] San Joaquin County interests were somewhat opposed because they were not included in the Water Forum process, which was specific to the American River Basin. There is now overall stakeholder support for the ARBCA/SNAGMA stage, most likely due to the collaborative structure of the initial Water Forum.

STAKEHOLDER PARTICIPATION

A CEQA document was prepared for the Water Forum action plan. The EIR was certified with no public comment in December 1999. This success was largely attributed to the focused outreach program and the consensus-based negotiations that resulted in development of the action plan in advance of EIR preparation.

ENVIRONMENTAL REVIEW

The environmental documentation for the Regional Plan and Sacramento North Area Conjunctive Use Program will start sometime in 2001, after the completion of Phase II of the Regional Plan.

TECHNICAL STUDIES

Phase I technical studies for the Regional Plan were completed by Montgomery Watson, in association with CH2M Hill and Bookman-Edmonson. A "Blue Ribbon" panel of experts was assembled to review the approach taken by the project consultant team and to comment on the technical studies. The approach and studies were well received by the panel.[83]

MONITORING PROGRAM

Once it has been fully implemented, the monitoring program will be administered by SNAGMA.

Financial Characteristics

Costs for the Groundwater Management Element of the Water Forum Agreement were not tracked separately from the other six elements of the agreement. Overall costs for the eight year Water Forum effort totaled nearly $13 million.[84] The Water Forum Successor Effort has an initial annual budget of $720,000 per year. Until 1998, CCOMWP bore Water Forum costs. Since then, the participants have shared the cost of the work: the City of Sacramento funds approximately thirty-five percent, the County funds approximately fifty percent, and other cities and districts fund fifteen percent of the effort.

The cost of the Regional Plan Phase I Study was $267,000. The Phase II Study will cost approximately $1,000,000.[85,86] Participants share these costs, and the finances are managed by San Juan Water District. In addition, SNAGMA has funded about $350,000 of studies in support of the conjunctive use program. Costs of the conjunctive use program will be identified in the Regional Plan Phase II Study.

Issues and Risks

Many of the issues, risks (e,g., hydrologic, economic, legal), operational details, and environmental impacts of the program will be determined in the Regional Plan Phase II Study and supporting CEQA documentation, which will be completed in 2001. Funding for project planning and implementation will be provided by the participating agencies. Water rate increases were estimated at four percent per agency in the Water Forum, but this estimate will be refined based on the Phase II Regional Plan work.

SNAGMA will manage the groundwater resources and administer program rules in the North Area. The risk to crops is expected to be minimal as most of the project area is urbanized.

Because the ARBCA/SNAGMA conjunctive use project is an outgrowth of the Water Forum process, political risks and risks of substantial opposition are expected to be minimal. All stakeholders, including potential project opponents, were identified at the outset and included in the process of interest-based negotiations. The principal role of the Water Forum Successor Effort is to review implementation of the conjunctive use program. As noted above, the Water Forum is cited as an example of an outstanding stakeholder effort to develop a cooperative water action plan, and political opposition is unlikely.

Conclusions

The Water Forum, and the subsequent formation of SNAGMA and ARBCA for the purposes of groundwater management and conjunctive use, is an example of the effectiveness of interest-based negotiation in addressing water resources issues in California. This case demonstrates that the process is not simple or quick. Rather, it shows that, in order to be successful, the process of building consensus and forming collaborative organizations requires planning, organization, education, negotiation, and implementation, as well as ongoing follow-up. Some of the factors that most likely contributed to the success of the Water Forum and subsequent efforts include:

GENERAL PLAN — having a clear General Plan for the region that demonstrates the need for securing water resources over the next thirty years provides a focus for generating discussion and planning.

FORUMS — SMWA provides a forum for communication and interaction among local water purveyors and was instrumental in carrying out the American River Water Resources Investigation and helping to initiate the formation of SNAGMA. Also, the Sacramento Area Water Works Association (SAWWA), founded in 1958, is a volunteer organization representing thirty-five Sacramento area water purveyors. SAWWA promotes communication, cooperation, and the integration of resources among its members.[87]

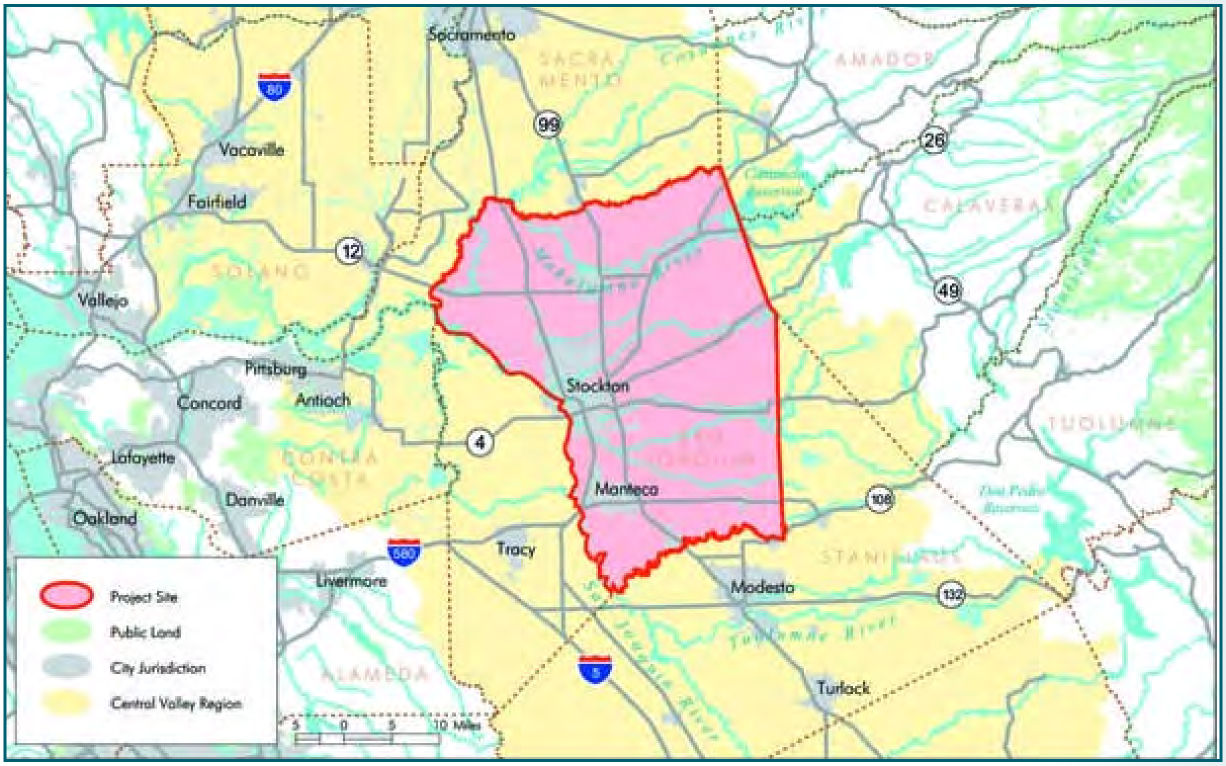
LEADERSHIP — having good leadership within the local water interests that recognized the need to reach out and include stakeholders in the Water Forum process is essential for success.

FACILITATION — recognizing the need for and retaining professional facilitation and mediation is a key element for success. Likewise, using interest-based negotiation and taking the time to train and educate the participating stakeholders is also crucial.

UNIFORM LAND USE — for the most part, the North Area has been extensively urbanized, and the remainder will most likely be urbanized over the next thirty years. Uniform land use contributes to the focus of the participants.

The Sacramento North Area Conjunctive Use Program is a good demonstration of how interest-based negotiations can lead to consensus on regional water issues and the formation of water plans. The Water Forum process led to an effective means of collective action for managing groundwater resources at the local level. As stated in the Water Forum Groundwater Management Element, this collective action is intended to avoid the "train wreck" that can occur when all overlying users exercise their right to pump groundwater beyond the sustainable yield of the basin. The Water Forum, and now SNAGMA and ARBCA, seek to prevent overdraft and the resultant disaster of divisive, protracted litigation and adjudication. Thus far, the effort has proven successful.

EAST BAY MUNICIPAL UTILITY DISTRICT/EAST SAN JOAQUIN PARTIES WATER AUTHORITY CONJUNCTIVE USE PROGRAM



Introduction

This case study reviews the efforts by the East Bay Municipal Utility District (EBMUD) and the East San Joaquin Parties Water Authority (ESJWPA) to jointly bank groundwater in Eastern San Joaquin County.

Physical Characteristics

SETTING

San Joaquin County is located at the northern end of the San Joaquin Valley, between the Sacramento-San Joaquin River Delta and the Sierra Nevada foothills. Eastern San Joaquin County is bounded by Sacramento County in the north; Amador, Calaveras and Stanislaus counties in the east; the Stanislaus River in the south; and the San Joaquin River and the San Joaquin River Delta in the west.[88]

San Joaquin County encompasses a total of 912,599 acres with about 600,000 acres of this area considered "Eastern San Joaquin County."[89] The majority of the land use in Eastern San Joaquin County is agricultural, and about six percent of the area is urban.[90] The major urban areas of Eastern San Joaquin County include the City of Stockton, City of Lodi, City of Manteca, Lathrop, Escalon and some unincorporated towns such as Lockeford, Clements and Thornton.

Water suppliers in Eastern San Joaquin County include the Woodbridge Irrigation District, the Stockton East Water District (SEWD), the North San Joaquin Water Conservation District, the Central San Joaquin Water Conservation District, the South San Joaquin Irrigation District, and the Oakdale Irrigation District. Additionally, San Joaquin County's Flood Control & Water Conservation District overlies the area.

Eastern San Joaquin County is traversed by the Mokelumne River in the north, the Calaveras River in the middle, and the Stanislaus River in the south at the San Joaquin/Stanislaus County line. Additionally, several small creeks cross the area. These include Dry Creek, Little Johns Creek, Lone Tree Creek, Duck Creek, Bear Creek, Mormon Slough, and Mosher Creek. Finally, six surface water reservoirs are operated within close proximity to the area: Camanche, Pardee, New Melones, New Hogan, Farmington, and Woodward Reservoirs.[91]

HYDROLOGY

San Joaquin County is within the northern portion of the San Joaquin River Hydrologic Region, as defined by the USGS, and overlies two groundwater basins—the Eastern San Joaquin County Groundwater Basin and the Tracy Groundwater Basin. The Eastern San Joaquin County Groundwater Basin is located east of the San Joaquin River and the delta and the Tracy Basin is west of the San Joaquin River. Sediments in the area are highly permeable.

Total agricultural consumption of water in San Joaquin County averages approximately 1,120,000 acre-feet per year. The municipal and industrial (urban) water demand is about 111,000 acre-feet per year.[92] Due to the relative lack of sufficient dry-year surface water rights in the San Joaquin County, the county has relied heavily on groundwater throughout its history. As a result, groundwater supplies approximately seventy percent of San Joaquin County's water needs.[93] The total groundwater usage in the county is estimated to be approximately 731,000 acre-feet per year, which exceeds the estimated safe yield of 618,000 acre-feet per year.[94] This mining of groundwater results in an estimated groundwater overdraft of 113,000 acre-feet per year.

Technical studies demonstrate that the groundwater overdraft problem has existed in Eastern San Joaquin County for several decades.[95] Two pronounced groundwater pumping depressions were observed in the region during the late 1940s and early 1950s. The largest of the two depressions is located in northeastern San Joaquin County between the Mokelumne and Stanislaus Rivers and is centered in the Stockton area. Here, groundwater levels are greater than seventy feet below sea level and as much as one hundred and fifty feet below pre-development levels.[96,97] One study indicates that the rate of groundwater withdrawal has exceeded recharge for at least fifty years. The overdraft has resulted in the intrusion of saline water into the aquifer below Stockton, with. some studies indicating that the saline water front is advancing at a rate of 140 to 150 lateral feet per year.[98,99] If the groundwater overdraft continues in the Stockton area, the saline migration will expand, resulting in a significant loss of Eastern San Joaquin County's groundwater resources.

The estimated overdraft for the northeastern part of the county is about 70,000 acre-feet per year, and a recent study shows that approximately 183,000 acre-feet per year is needed to overcome the impacts of the groundwater overdraft.[100,101] As a result, the ongoing overdraft has dewatered an estimated three million acre-feet and created considerable storage capacity in the Eastern San Joaquin County groundwater basin.[102]

The East Bay Municipal Utility District's 1993 Water Supply Management Program describes groundwater use as a key element of EBMUD's water supply reliability strategy. The District's engineering and environmental work clearly demonstrates the technical feasibility of recharging and extracting surface water in the Eastern San Joaquin County Groundwater Basin. The EBMUD literature also points out that, while it is technically feasible to bank water in the area, institutional issues need to be resolved before a project can move forward.[103] The following discussion provides a brief history of EBMUD's involvement in water banking in Eastern San Joaquin County.

Project History

Water officials and the public have been aware of the groundwater overdraft problem in Eastern San Joaquin for many years. In 1971, the serious nature of the situation prompted the California State Legislature to take special action. In recognizing the problem, the Legislature stated:

> *"The water supplies in the underground basin in the area of Stockton East Water District are insufficient to meet the water demands of the area, and, because of the geologic conditions peculiar to the area and because excessive pumping has seriously depleted the underground water storage, there has been an intrusion of saline waters into the underground water basin causing serious water quality deterioration and the destruction of the usefulness of a portion of the underground water basin. Further excessive pumping, without proper management of the underground water basin is certain to destroy the usefulness of a major portion of the underground water basin and endanger the health of and welfare of the district."*[104]

The Legislature found that the overdraft problem was broad and complex and that neither the urban nor the agricultural interests could solve the problem by themselves but instead must make a joint effort to reach a solution. Policymakers have recognized the overdraft problem in other forums as well. For example, Section 1011.5 of the Water Code mandates that the overdraft in the Eastern San Joaquin County Groundwater Basin be halted by 2007 as a condition for exportation of groundwater. And, the California Department of Water Resources (DWR) in Bulletin 118-80 identified the groundwater underlying Eastern San Joaquin County as subject to critical conditions of overdraft.

The recognition of the overdraft problem in Eastern San Joaquin County led to a number of proposals for dealing with the situation. Several options have been explored, including the reoperation of Farmington Reservoir to provide recharge water and a regional canal connecting the Folsom South Canal to the lower Farmington Canal to make use of water from the Calaveras and Stanislaus Rivers. One of the proposals involves participating in a conjunctive use project with EBMUD, where, during certain years, a portion of EBMUD's Mokelumne River Water or its CVP water would be banked in the Eastern San Joaquin County Groundwater Basin prior to being diverted into the Mokelumne Aqueduct.[105] This proposal was discussed in the EBMUD 1993 Water Supply Management Program (WSMP) and is the focus of this case study.[106,107]

EBMUD's involvement in Eastern San Joaquin County groundwater issues can be traced back to 1937 when concerns were raised about Mokelumne River diversions and groundwater in the Lodi area. EBMUD currently monitors groundwater levels as a part of an agreement with the City of Lodi. In 1981, the San Joaquin County Flood Control and Water Conservation District retained the firm of Brown and Caldwell to study groundwater conditions in Eastern San Joaquin County (Brown and Caldwell Study). The Eastern San Joaquin Water Users Association—composed of the North San Joaquin Water Conservation District, the Woodbridge Irrigation District, the Stockton East Water District, the Central San Joaquin Water Conservation District, the County Flood Control and Water Conservation District, and the Woodbridge Water Users Conservation District—supported the need for this study. Participants in the study Policy Advisory Committee included the City of Stockton, City of

Lodi, California Water Service Company, and EBMUD. The members of the Eastern San Joaquin Water Users Association, with the Cities of Lodi and Stockton (and the California Water Service Company as a non-voting member), eventually formed the East San Joaquin Parties Water Authority (ESJPWA) for the purpose of negotiating a groundwater recharge project with EBMUD.

The goal of the Brown and Caldwell Study was to determine the relative effects of various water supply alternatives on the Eastern San Joaquin County groundwater basin. Completed in 1985, the study found that development of a plan to optimize the use of surface water and groundwater supplies was technically feasible and economically attractive. However, the study notes that much technical, legal, economic, and institutional work would need to be completed before a conjunctive use program could be considered.[108]

The prolonged drought of 1987–1992 caused the groundwater levels in San Joaquin County to decline sharply.[109] This allowed the saline waterfront to encroach further eastward, degrading the quality of the groundwater in the eastern part of the county (Fall 1993 Groundwater Report). The drought also induced landowners to install wells in the southwest area of San Joaquin County for groundwater export via the adjacent CVP aqueduct facilities (the Delta Mendota Canal). These events, plus growth in the county, underscored the need to move forward with some form of supplemental water program.

The idea to actively pursue a recharge project for Eastern San Joaquin County originated with Stockton East Water District.[110] As a major water agency within Eastern San Joaquin County responsible for providing supplemental surface water supplies, SEWD recognized the seriousness of the overdraft problem and the need to explore regional solutions. The district's initiative, coupled with some active leadership within San Joaquin County and the development of EBMUD's Water Supply Management Program, led to negotiations between Eastern San Joaquin County water interests and EBMUD in 1994.[111,112]

In 1995–96, the Eastern San Joaquin County water interests, consisting of the San Joaquin County Flood Control and Water Conservation District, the Cities of Stockton and Lodi, SEWD, Central San Joaquin Water Conservation District, Woodbridge Irrigation District, North San Joaquin Water Conservation District, and the California Water Service Company (as an associate member), formed the East San Joaquin Parties Water Authority (ESJPWA), a joint powers authority.[113] The stated purpose of the ESJPWA is to plan a project or projects to meet the water deficiencies of Eastern San Joaquin County, either alone or in conjunction with EBMUD and/or other public entities.[114]

The ESJPWA negotiations with EBMUD resulted in a 1995 agreement to pursue jointly funded technical studies.[115] The technical studies were completed in 1996 and found that a mutually beneficial program would entail recharging 40,000 acre-feet per year in about half of all years into the basin, while extracting about 50,000 acre-feet of water in one out of four years.[116] The study looked at *in lieu* conjunctive use and injection/extraction as options. It concluded that the least expensive option would be to use dual-purpose aquifer storage and recovery wells located near EBMUD's Mokelumne River Aqueduct (MRA). Capital facilities for this option were estimated to cost $25 million, as opposed to $90 million for *in lieu* recharge facilities.[117] The MRA injection/extraction option would allow EBMUD to take advantage of normal weather and wet weather flows from the Mokelumne River.

The findings of the 1996 technical studies led to the execution of a 1997 Memorandum of Agreement (MOA) between ESJPWA and EBMUD to demonstrate the feasibility of the injection and extraction of surface water into the Eastern San Joaquin County Groundwater Basin.[118] The purpose of the proposed project was to test the reaction of the aquifer to injection and extraction, the water quality impacts and optimal rates of injection and extraction. The data generated by this pilot project would provide the necessary information for the design of full-scale injection/extraction facilities.

The proposed project, which became the Beckman Test Injection/Extraction Project (Beckman Test Project), was designed to inject 3,000 acre-feet of Mokelumne River Water from the MRA into a site adjacent to the MRA. Per the MOA, EBMUD would sell the water to ESJPWA; EBMUD would have the ability to recover up to fifty percent of the injected water (1500 acre-feet). The project was operated for a nine month period during 1997–1998 and demonstrated the feasibility of injecting up to 500 gallons per minute.[119] While the project performed as expected, the Beckman Test Project created an institutional controversy within San Joaquin County as a result of EBMUD filing an application for the export of water extracted from the project.

In 1996, in partial response to the groundwater overdraft in the southwest portion of the County that occurred during the drought, San Joaquin County adopted an ordinance establishing a permit process for exportation of groundwater. In 1997, EBMUD became the first entity to apply for a permit when it requested a permit for export of water from the Beckman Test Project site via the MRA.[120] Per the requirements of the County ordinance, the Advisory Water Commission of the San Joaquin County Flood Control and Water Conservation District reviewed the permit. The permit process includes the opportunity for public comment at the Commission review. Significant opposition to the permit application was voiced by the overlying farmer/landowners, including the San Joaquin Farm Bureau Federation, which was concerned about granting EBMUD access to the Eastern San Joaquin Groundwater Basin.[121] As a result, only three of the nineteen Commission members present (out of a total twenty-two members) voted to support the permit.[122,123] Thus, the permit was denied and no water was exported from the Beckman Test Project.

The application triggered nearly two of years of review of the protections afforded by the 1996 Ordinance. The ordinance was amended in June 2000 to incorporate measures to ensure that local groundwater users have enough water. The amendments adopted portions of the Kern Water Bank operating rules, modified to meet the needs of San Joaquin County. The amendment requires the submission of more detailed project information, the installation of at least three monitoring wells, a limit on the amount of water that can be exported to assure a net gain in usable water underlying the project, requirements for the spacing of extraction wells and buffer zones, limits on extraction times and periods, the formation of a monitoring committee, and a provision that the project shall not create conditions that are worse than conditions in the absence of the project (the so-called "Golden Rule"). The permit approval is made by the County Board of Supervisors. However, before approving any permit application, the Board of Supervisors must find that the proposed project will not operate to the injury of the reasonable and beneficial uses of the overlying groundwater users.[124]

With the adoption of the amended ordinance and the completion of the Beckman Test Project, ESJPWA and EBMUD proposed to move ahead with the Eastern San Joaquin Groundwater Bank #1 Project. This project would use both *in lieu* pumping and groundwater injection methods to bank Mokelumne River water. Injection/extraction wells would be constructed near the MRA in the North San Joaquin Water Conservation District area. The Eastern San Joaquin Groundwater Bank #1 Project proposed to recharge an average of 7,000 acre-feet per year and extract an annual average of 3,500 acre-feet of water per year. The estimated cost for this project was $25 million.[125]

ESJPWA began soliciting partners to provide water and/or funds to assist in advancing the project. This triggered the opposition of local interests who feared the encroachment of outside agencies into the Eastern San Joaquin Groundwater Basin, even with the protections provided by the amended County ordinance in place.

As of September 2000, the ESJPWA intended to move forward with the Eastern San Joaquin Groundwater Project, utilizing the lessons learned from the Beckman Test Project. The ESJPWA representatives believed, based on the ordinance revision process, that they understood what level of information is required to satisfy the Advisory Water Commission needs, and ESJPWA planned to develop the project along these lines. Also, ESJPWA intended to incorporate an ongoing public outreach effort regarding the project.[126] ESJPWA and EBMUD stated that they could work within the requirements of the amended County Groundwater Extraction and Exportation Ordinance. Eastern San Joaquin Parties Water Authority disbanded on June 30, 2000. The future of this project is therefore uncertain.

Table 2

EASTERN SAN JOAQUIN COUNTY/EAST BAY MUNICIPAL UTILITY DISTRICT GROUNDWATER BANKING PROJECT CHRONOLOGY	
EVENT	DATE
Brown and Caldwell are retained by San Joaquin County Flood Control & Water Conservation District to study groundwater conditions in Eastern San Joaquin County—EBMUD is a study participant.	1981
Brown and Caldwell study is completed. Study finds 200,000 af per year of surface water needed to stabilize groundwater basin, recommends Folsom South Canal option and/or New Melones be used as water source.	1985
Prolonged drought—farmers in Tracy area install wells for groundwater export.	1987–1992
San Joaquin County Flood Control & Water Conservation District groundwater monitoring demonstrates that saline front has encroached farther east towards Stockton (drought impact).	1993
Active negotiations begin between Eastern San Joaquin County water producers and EBMUD regarding a joint conjunctive use project.	1994
East San Joaquin Parties enter into an agreement with EBMUD to evaluate a joint groundwater storage conjunctive use program. Montgomery Watson, in conjunction with CH2M Hill, is selected to perform the study.	1995
East San Joaquin Parties Joint Exercise of Powers Agreement is executed. ESJWPA's stated purpose is to plan projects to meet water deficiencies of Eastern San Joaquin County.	1996
San Joaquin County adopts a groundwater extraction and export ordinance.	1996
Montgomery Watson issues Mokelumne Aquifer Recharge and Storage Project Final Report. Stanislaus & American River injection and *in lieu* options are presented. Folsom Canal South option plus Mokelumne River options are also presented.	1996
EBMUD and ESJWPA enter into a Memorandum of Agreement to demonstrate the feasibility of injection and extraction of surface water into the Eastern San Joaquin County Groundwater Basin. EBMUD will provide 3000 af of water to ESJWPA for $1/af. EBMUD can extract up 50% of the stored water.	1997
EBMUD files for an export permit pursuant to Division 7 of Title 5 of the Groundwater Extraction and Exportation Ordinance of San Joaquin County. Local interests strongly oppose issuing the permit. The Advisory Water Commission (AWC) approves environmental documentation, but the permit application subsequently fails.	1998
Beckman Test Injection/Extraction Project constructed and operated. Boyle Engineering Corp. is project consultant. Mokelumne River Aqueduct is used to supply water.	1997–1998
Boyle Engineering releases final report on Beckman Project. Report concludes that injection rates of 500 gallons per minute, or more, per well are feasible. Extraction rates were as projected.	1999
After a series of extensive reviews, the San Joaquin County Board of Supervisors approves an amendment to the Groundwater Extraction and Exportation Ordinance that limits groundwater exports, creates a monitoring committee for projects and requires groundwater banking projects to provide a net increase in groundwater in the basin.	May 2000
ESJWPA presents proposed Groundwater Bank No. 1 Project ("10 Well Project"). Information from the Beckman Project will be used for design. EBMUD will participate and Mokelumne River water is the proposed supply source. ESJWPA solicits partners for project.	August 2000
San Joaquin Farm Bureau Federation (SJFB) publicly opposes participation by outside interests in any groundwater banking/extraction project within San Joaquin County. The Farm Bureau states opposition to ESJWPA soliciting outside partners.	August 2000
ESJWPA charter formally expired June 2000—this is not recognized until November 2000.	November 2000
Members of former ESJWPA form northeastern San Joaquin County Groundwater Banking Authority.	February 2001

Institutional Arrangements

The proposed source of the banked water is the Mokelumne River and, potentially, water diverted from the Sacramento River. EBMUD has rights to 360,000 acre-feet per year of Mokelumne River water, but the district has inadequate storage and the Mokelumne River flows are highly variable, ranging from 80,000 to 1.8 million acre-feet per year.[127]

The Beckman Test Injection/Extraction Project was sited on land owned by Mr. Charles Beckman, near the Mokelumne River Aqueduct (MRA) to minimize conveyance costs. Similarly, the proposed Eastern San Joaquin County Groundwater Bank No.1 will be located near the MRA within the North San Joaquin Water Conservation District, in order to minimize costs of pipes for distribution and extraction. The proposal is for an aquifer storage and recovery (ASR) project, where banking would be accomplished by approximately ten injection/extraction wells. Water would then be conveyed to end-users via the Mokelumne River Aqueduct. Water remaining in the basin would be used for overdraft correction.

BENEFICIARIES

The project includes two groups of intended beneficiaries—EBMUD and the ESJPWA members. EBMUD will benefit by the addition of water storage to improve the reliability of its Mokelumne River supply. EBMUD is a participant due to its Mokelumne River rights and the proximity of its facilities (MRA) to Eastern San Joaquin County. The ESJWPA represents agencies in the Eastern San Joaquin County area that are most affected by the groundwater overdraft. Incidental beneficiaries will consist of overlying landowners who are groundwater users; groundwater users in Eastern San Joaquin County would benefit from the improved groundwater levels. The stored water would help to correct the overdraft created by agricultural pumping and municipal and industrial demands in Eastern San Joaquin County.

PROJECT OPPOSITION

For the most part, project opposition consisted of the San Joaquin Farm Bureau and Central Delta Water Agency. Their major concern was that it was too risky to bring in an outside agency and give that agency access to the local groundwater basin. Outside agencies were viewed as predatory organizations that would take the water when they needed it, without considering San Joaquin County's needs.[128] They also feared a loss of water rights if these agencies put a "straw in the aquifer." Paul Sanguinetti, past San Joaquin Farm Bureau President, member of the SEWD board and Stockton area farmer, expressed the essence of the local fears by stating that dealing with EBMUD was like "playing with a loaded gun" and that once the area experienced several dry years in a row, "there's no way we're going to stop them from exporting that water out of the county. No way. We'll have to stop pumping here."[129] The San Joaquin Farm Bureau Federation, representing the local farming interests, elaborated these concerns in public forums. The Executive Director, Russ Matthews, stated "everyone is in favor of recharging groundwater—as long as that water remains in the area and is not exported out of the county."[130]

In response to the ESJPWA call for partners, the San Joaquin Farm Bureau Federation interviewed local political leaders and Farm Bureau officers and members regarding the proposal. The Farm Bureau elicited responses to the effect that: solicitation of partners was premature until an export permit was obtained; banking by a local agency was preferable because "they'd have a stake in the groundwater situation and would work for both themselves and the area," overlooking the fact that the ESJPWA was comprised wholly of local agencies; San Joaquin county's needs should come first; "our" water rights might be lost; and the county should undertake groundwater banking itself for local control and benefit. It was also believed that, once involved, it would be expensive to get outside municipal water agencies out of the aquifer (invoking the Owens

Valley episode where MWD purchased overlying lands in order to appropriate the groundwater). In an earlier article, the San Joaquin Farm Bureau Federation discussed the SEWD technical study of recharging the Eastern San Joaquin County Groundwater Basin with winter run-off through percolation ponds. The article showed that local interests were supportive of the project due to the fact that a local San Joaquin County agency would be in charge, rather than an outside agency. The two articles, plus the statements of individuals interviewed for this study, indicated that the major issue was the fear of an outside entity gaining control of groundwater in San Joaquin County. However, the Farm Bureau did support an amended export ordinance that provided greater protections for overlying landowners.

STAKEHOLDER AND PUBLIC PARTICIPATION

For the most part, public participation took place at the Advisory Water Commission level and at the ESJPWA Board meetings. ESJPWA members reported project information back to their respective Boards and Councils. The ESJWPA Board was composed of the majority of the agency stakeholders in the northern portion of Eastern San Joaquin County (the southern agencies, such as the cities of Manteca, Lathrop, Escalon and the South San Joaquin Irrigation District are participating in a regional plan to use the District's surface water). Overlying landowners and other agencies could voice their concerns regarding the project through the San Joaquin County Water Advisory Commission and the Board of Supervisors. San Joaquin County is currently conducting a stakeholder/consensus building effort for the development of a county-wide Water Master Plan. This effort includes all of the stakeholders that are affected by the proposed groundwater banking project.

ENVIRONMENTAL REVIEW

If this project continues, the Beckman Test Project site and proposed project site will be located on farmland near the MRA. There are no environmental or water related issues that have been currently identified. The Beckman Test Project was carefully monitored to check for impacts to adjacent wells and the groundwater table. No detrimental impacts to adjacent wells occurred during the test project, and the ground surface was not impacted by injection.

A specific site for the proposed Eastern San Joaquin Groundwater Bank No. 1 has not been selected. The proposal calls for a site south of the Mokelumne River, adjacent to the MRA and within the North San Joaquin Water Conservation District area.

A Negative Declaration was approved by ESJWPA for the Beckman Test Project. Environmental compliance documentation has not been completed on the San Joaquin County Groundwater Bank No. 1 Project.

TECHNICAL STUDIES

There was no dispute regarding the various technical studies describing the overdraft problem in Eastern San Joaquin County. The Beckman Test Injection/Extraction Project Final Report prepared by Boyle Engineering Corporation was a very thorough and well-documented study. According to ESJWPA participants and published reports, the issue was not the thoroughness or validity of the technical studies—it was the distrust of an outside agency. The concern was that an outside agency could become overly reliant on the Eastern San Joaquin County groundwater basin, draining the region of its groundwater resources.[131] The issue is not a technical one; it is an institutional and political issue, and local interests must be assured that the potential third party impacts are mitigated before a project can move forward.[132]

Monitoring Program

The Beckman Test Project incorporated a thorough monitoring program to check groundwater levels and water quality impacts. Staff members of the ESJPWA performed daily monitoring of the Beckman Test Project. The Beckman Test Project also incorporated careful monitoring to determine if water quality problems might be encountered by injecting MRA water. The Technical Advisory Committee for the Beckman Test Project adopted a turbidity limit of 2.0 NTU to avoid well plugging. The project Final Report showed no water quality issues and recommended that the injection of surface water be suspended when MRA turbidities exceeded 2.0 NTUs.

The 2000 amendment to the San Joaquin County Groundwater Extraction and Export Ordinance required the establishment of a five-member monitoring committee for any permitted groundwater banking project within San Joaquin County. This requirement for a monitoring committee was modeled after the Kern Water Bank monitoring committee requirements and applies to any permitted project in San Joaquin County. Thus, the proposed San Joaquin County Groundwater Bank No. 1 will require the establishment of such a monitoring committee.

Per the ordinance, the monitoring committee will consist of representatives from the following agencies and stakeholder interests: the County Public Works; the County Public Health Services; the permittee; the local agency providing water within the project service area; and owners of land within two miles of the project location. The monitoring committee will set criteria to determine if there is well interference caused by the project and can engage the services of a professional groundwater specialist to provide assistance. The committee will also maintain records of the recharge and recovery activities related to the project and make recommendations to the San Joaquin County Advisory Water Commission for project modifications based on evaluation of monitoring data.[133]

Financial Characteristics

Costs for the design and construction of facilities—outside of the EBMUD right-of-way, permitting, right-of-way acquisition and environmental documentation for the Beckman Test Project—were borne by the ESJPWA. The design and construction of facilities within the EBMUD right-of-way were borne by EBMUD.[134]

The proposed San Joaquin County Groundwater Bank No. 1 will cost an estimated $25 million.[135] The cost shares are yet to be determined. The value of the water produced is estimated at $400 per acre-foot.

Issues and Risks

There is no full-scale project on line at present; therefore, hydrologic risks (e.g., aquifer leakage, pumping limitations, reduced infiltration) cannot be completely addressed. However, it should be noted that the San Joaquin County Groundwater Extraction and Exportation Ordinance does address these risks as follows:

- Extraction for export is limited to an amount that ensures that the project will result in a net addition to the usable groundwater underlying the project.
- Extraction wells may be spaced to limit impacts and an appropriate number of wells required to allow rotation.
- Buffer areas may be required between extraction wells and neighboring users.
- Annual, seasonal, or monthly limits and time restrictions can be placed on extraction rates.

- Pumping rates can be adjusted or terminated to reduce impacts.
- Exportation cannot result in lowering the average static water level in the project area by more than fifteen feet.
- A monitoring committee is required for each project.
- The project cannot create conditions that are worse than conditions absent the project.
- Lowering neighboring pump bowls to accommodate lower groundwater levels may be required to mitigate unavoidable adverse impacts.
- The cost of providing alternative water supplies to an impacted overlying user may be required of the project owner/operator.
- Financial compensation may be provided to an impacted overlying user by the project owner/operator.

The conditions and mitigation measures listed above are to be imposed by the County Board of Supervisors per the amended ordinance.

The ESPJWA and EBMUD 1997 Memorandum of Agreement provides that each party will indemnify the other. Both agencies agreed to equally share the costs of any permit challenges. It is assumed that similar contract provisions will be incorporated in future agreements.[136]

The Beckman Test Project and subsequent permit application did bring to the foreground the issues and concerns of the community regarding the EBMUD/ESJPWA partnership. This will allow the project participants to design the Eastern San Joaquin Groundwater Bank No. 1 Project in a way that responds to the concerns of the local community.

Conclusions

The ESJPWA/EBMUD experience in San Joaquin County is not unique in that the issues of local control of groundwater and the protection of overlying landowner rights to groundwater are a common theme in the San Joaquin Valley. As an example of this commonality, parallels can be drawn between this case and the Madera Ranch/USBR experience. Similarities between the two cases include:

- A groundwater basin in a state of overdraft, with potential capacity for recharge.
- Proximity to surface water conveyance features, providing for convenient put and take operations.
- An outside agency willing to consider banking within the county.
- Significant overlying landowner opposition to the proposed project.

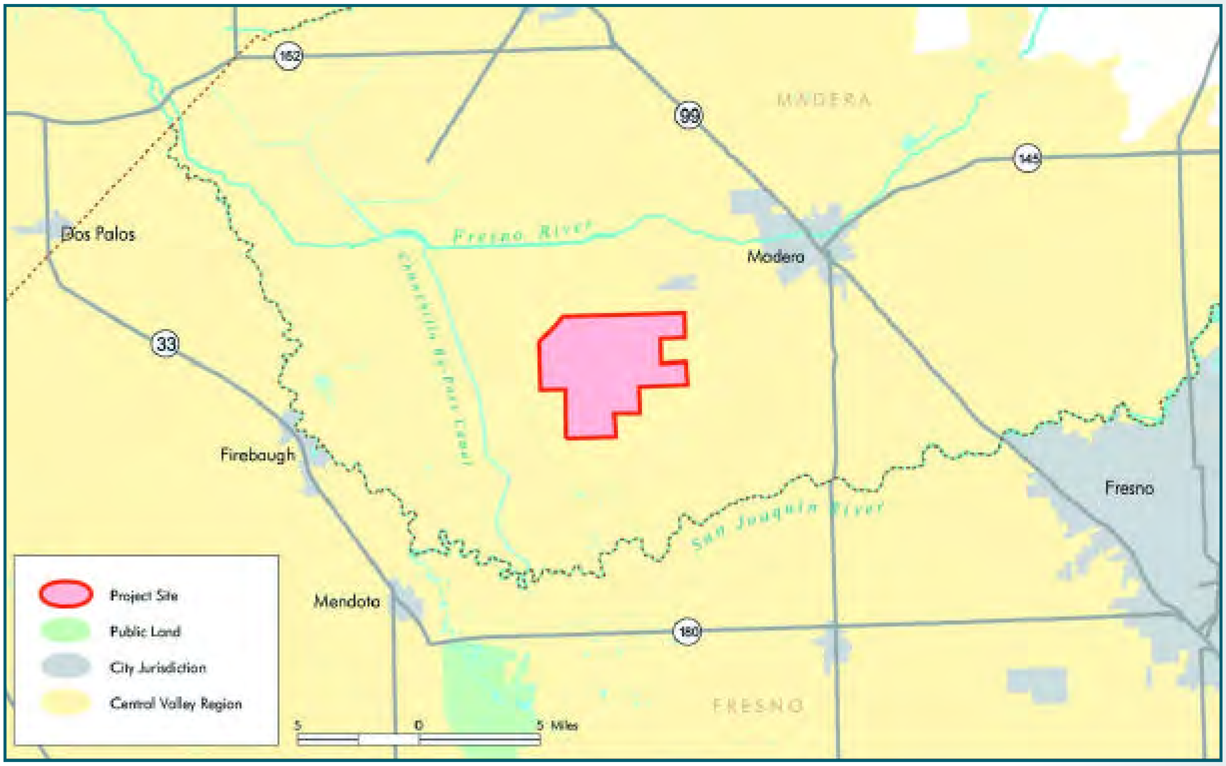
While the two cases appear to be essentially similar, there are significant differences. The differences can be summarized as follows:

- The presence in San Joaquin County of a groundwater extraction and exportation ordinance developed concurrent with, and in response to, the initial project proposal.
- The presence in San Joaquin County of a water advisory commission with authority to condition/approve/disapprove permits to extract and export groundwater.

> This commission also provides a forum for the multiple water interests within San Joaquin County, including agencies outside of the groundwater basin (this did not exist in Madera County).
>
> - The presence in San Joaquin of a joint powers authority made up of agencies in the area of overdraft, serving as project proponents.
> - The lack, in San Joaquin County, of a property transaction and time limit for pur chase (pending land sale) to make the project workable.
> - Multiple local water agencies investigating significant local groundwater banking projects within San Joaquin County (SEWD, San Luis Delta Mendota Water Users Authority, City of Tracy).

These differences create a different dynamic in San Joaquin County than the Madera case. The test of the ESJPWA/EBMUD will be the permit application for the proposed Eastern San Joaquin Groundwater Bank No. 1. The permitting process and decision will indicate how successful the ordinance amendment process was and whether or not local landowners are satisfied with its protections.

MADERA RANCH GROUNDWATER BANK PROJECT



Introduction

This case study reviews the Madera Ranch Groundwater Bank Project as proposed by Mr. Heber Perrett and the U.S. Bureau of Reclamation (USBR) prior to the purchase of the Madera Ranch property by the Azurix Madera Corporation in 1999.

Physical Characteristics

SETTING

Madera Ranch is a 13,600-acre property in Madera County, approximately eight to ten miles southwest of the City of Madera. Approximately 1,000 acres of the Madera Ranch property are irrigated, and the balance (12,600 acres) is used either for dryland farming or grasslands. The project site is located on the lower alluvial floodplain of the San Joaquin and Fresno Rivers in the southernmost portion of the San Joaquin River Hydrologic Region, (see Figure 2 on the following page). The Madera Ranch property overlies what is commonly referred to as the Madera Groundwater Basin.

The project site is situated in an unincorporated portion of Madera County. Madera Irrigation District overlies two sections (1,497 acres) on the eastern edge of the Madera Ranch property and is also directly north of and adjacent to the project site. Gravelly Ford Water District overlies two sections (1,282 acres) along the southeastern edge of the property.

HYDROLOGY

Ongoing monitoring and studies demonstrate that the Madera Groundwater Basin, including the groundwater table underlying the ranch, is in a state of overdraft that has been exacerbated by the drought periods of 1976–1977 and 1987–1992.[137] Groundwater levels in the Madera Basin dropped from 10 to 120 feet from 1960 to 1990[138] and the approximate average annual decline in static groundwater levels within the Madera Irrigation District is 1.25 feet per year.[139] Currently, the depth of groundwater in the Madera Basin is, on the average, 40 feet below pre-drought levels; thus, there should be space in the basin for groundwater recharge.[140]

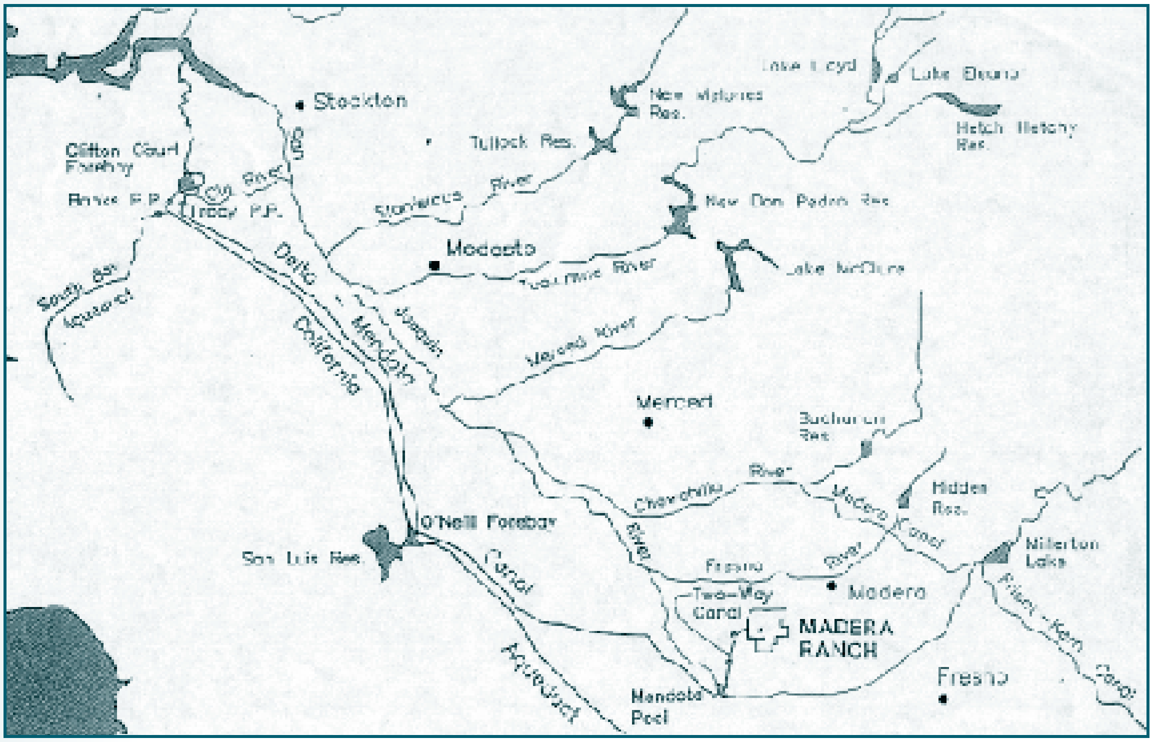
Groundwater pumping in the Madera Basin is estimated to supply about one half of Madera County's irrigation needs. The Madera Irrigation District provides surface water deliveries to a 128,294 acre service area adjacent to the Madera Ranch site. The ten year average of surface water deliveries to the Madera Irrigation District Service area is 95,557 acre-feet per year.[141]

The Madera Ranch Groundwater Bank Project site is ideally located to take advantage of existing water project facilities for the conveyance of recharge water to the site. The Madera Ranch site is situated near the southern portion of the Delta-Mendota Canal and Mendota Pool, potentially enabling surplus Central Valley Project (CVP) water to be conveyed to the project site—with the construction of minimal facilities—for percolation into the basin. Additionally, the project site location could also allow for the conveyance of water from the San Joaquin River via an improved Gravelly Ford, a canal facility that currently can deliver water from the San Joaquin River to lands adjacent to the Madera Ranch site.

The location of the Madera Ranch property above the Madera Groundwater Basin, its proximity to existing water project conveyance features, and the fact that the property is one of the last large unfarmed pieces of privately held land in the San Joaquin Valley make it a logical site to investigate for a potential groundwater banking project.

MADERA RANCH GROUNDWATER BANK

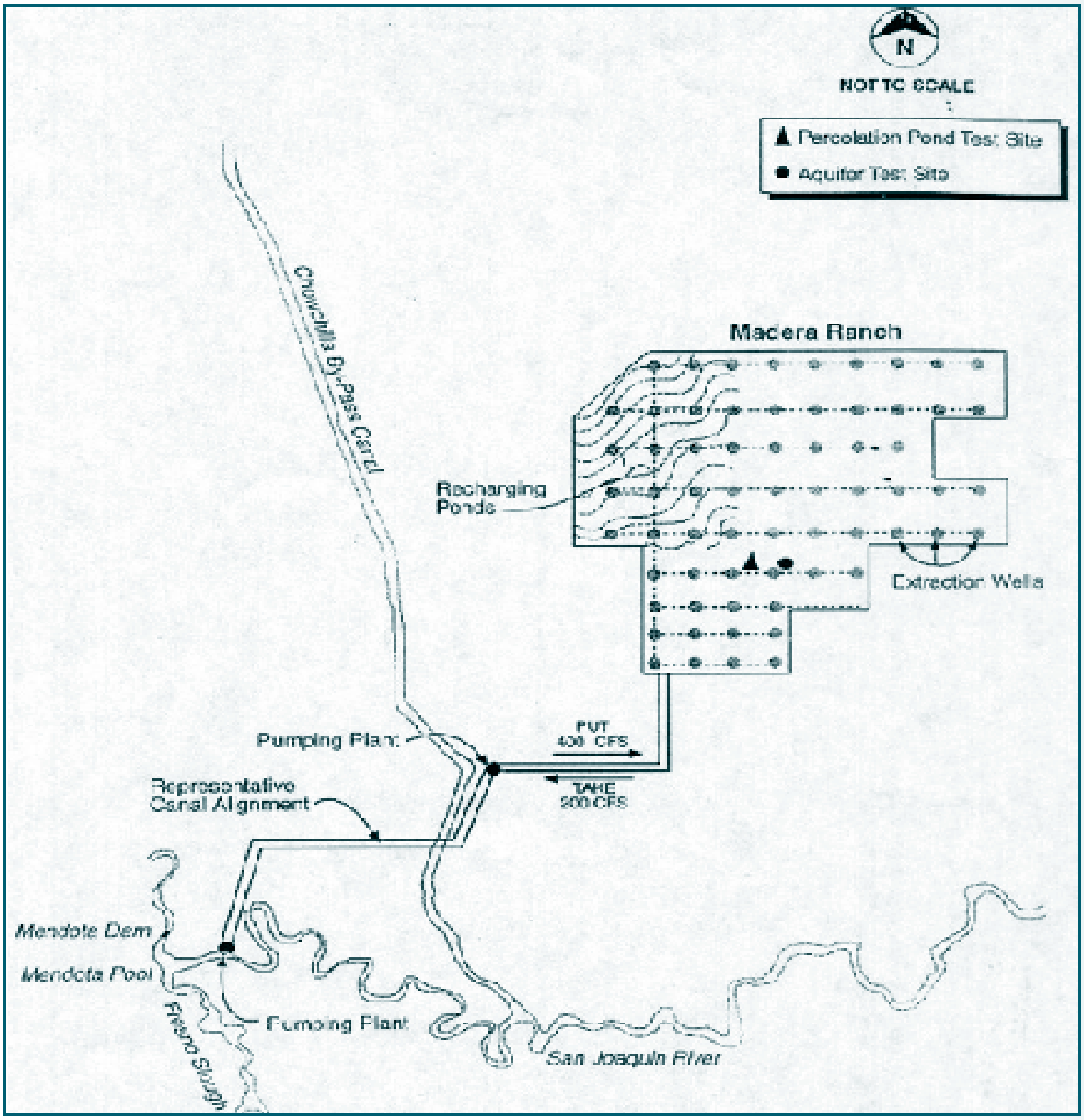
Figure 2



The original Madera Ranch project concept involved conveying surplus CVP water from the Delta to the Mendota Pool and then diverting this water to the Madera Ranch Project site. This could be augmented by additional water pumped under the joint point of diversion as part of a water reserve account proposed by USBR.[142] The CVP can only pump 4,200 cubic feet per second (cfs) from the San Joaquin River Delta due to conveyance capacity constraints downstream from the Tracy Pumping Plant. By utilizing the joint point of diversion, the 400 cfs not pumped by the CVP due to the constraints can be pumped by the State Water Project (SWP) at the Banks Pumping Plant and delivered for CVP uses, such as groundwater banking. Additional sources might include water purchased by the USBR as part of its Land Retirement Program and water from non-federal water users. Flood flows diverted from the Chowchilla Bypass flood channel were also considered but rejected because the operation would produce an average annual increase in yield of less than 3,000 acre-feet and the cost of the requisite additional facilities could not be justified.[143]

A gravity turnout and a two-way canal with pumping plants would be used to convey the water from the Mendota Pool to the Madera Ranch Project site and then percolated using recharge wetland ponds. Water extracted from the bank would be reconveyed to the Mendota Pool for delivery to end-users. Figure 3 shows a conceptual schematic of the conveyance, recharge and extraction facilities originally proposed for the project.

MADERA RANCH GROUNDWATER BANK / CONCEPTUAL DRAWING
Figure 3



Project History

On August 13, 1996, Mr. Heber Perrett, the owner of the Madera Ranch site at that time, presented the original Madera Ranch Groundwater Bank Project proposal to the USBR. The Bureau was interested in the Project to store water reserve account water. This reserve account is designed to assist the USBR in meeting the requirements of the Central Valley Project Improvement Act (CVPIA), improving CVP operations, and for drought year water supplies. An estimated maximum of 390,000 acre-feet of surface water was proposed for storage in the Madera Ranch Groundwater Bank Project, with 100,000 acre-feet reserved for critically dry years.[144]

The property owner's offer prompted the USBR to undertake a preliminary investigation to determine if fatal flaws existed in the Madera Ranch project proposal. The San Luis-Delta Mendota Water Authority (SLDMWA) and the Santa Clara Valley Water District (SCVWD), as potential groundwater bank partners, provided the information needed to model delivery and extraction operations at the project site. This preliminary investigation was also designed to evaluate the physical suitability of the Madera Ranch site for banking water.

The preliminary investigation, completed in July 1997, found no obvious fatal flaws and recommended a phased evaluation of the proposed banking project.[145] The first phase was initiated in July 1997 and completed in April 1998. The Phase 1 Investigation included the results of a geologic and hydrologic study by Bookman-Edmonson that was completed for Heber Perrett (February 1998). The investigation also provided a brief review of local issues, environmental concerns, operational concerns and financial issues. This preliminary investigation culminated in a Phase 1 Report that found that the Madera Ranch site has potential for groundwater banking development and is worth further investigation. However, it also pledged that further pursuit of the project would be halted if any fatal flaw, with no remedy, was revealed at any time by the Phase 2 Investigation.[146] The Phase 1 Report recommended proceeding with a more detailed Phase 2 Investigation of two project alternatives: a multi-year commitment by USBR to lease facilities and services developed by Mr. Perrett or an option for USBR to purchase the Madera Ranch Property for development of the project by USBR.[147] The Phase 2 Investigation also intended to also make recommendations on permit applications, public involvement, environmental compliance development under the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA), necessary negotiated agreements and congressional authorizations.[148]

After the completion of the Phase 1 Report, opposition by the Madera County Board of Supervisors, the Madera City Council, the Madera Ranch Oversight Committee, area farmers, regional water districts and local stakeholders caused USBR to reconsider the project planning process.[149] The project timeline was extended an additional 18 to 24 months to give the Bureau time to address local stakeholder concerns.[150] A request by USBR to CALFED for $14.5 million in funding for the purchase of the property was rejected because of the local opposition, and CALFED indicated it would not reconsider the project until local concerns had been adequately addressed.[151]

Subsequently, USBR abandoned the project and the Madera Ranch property was sold to Azurix Madera Corporation (a Texas-based water development corporation owned in part by the Enron Corporation) in October of 1999 for a reported $31 million.[152] Azurix is currently pursuing the development of the Madera Ranch Groundwater Bank Project with the objective of providing banking participants with storage space for their water.[153]

A summary chronology of major project events is illustrated by Table 3 of this report.

Table 3

MADERA RANCH GROUNDWATER BANKING PROJECT CHRONOLOGY 1996–1999

EVENT	DATE
Mr. Heber Perrett purchases the Madera Ranch property	May 1991
USBR receives Madera Ranch Groundwater Banking Project Proposal	August 1996
Preliminary evaluation is completed (fatal flaws analysis, capacity analysis)	July 1997
Agreement for two-phase investigation is made	November 1997
Phase 1 Investigation starts	December 1997
USBR issues press release and holds two public briefings	January 1998
Bookman-Edmonston provides study results to Perrett and USBR	February 1998
Phase 1 Report completed (field tests, technical issues identified)	April 1998
Perrett conducts on-site tour of Madera Ranch for local landowners	May 1998
Area farmers and representatives of local water districts form grassroots Madera Ranch Oversight Committee to monitor project	August 1998
Oversight Committee gathers information and makes presentations opposing the project	September1998–March 1999
USBR releases Bookman-Edmonston study to the general public	September 1998
Emergency congressional appropriation attempts to fund land acquisition of Madera Ranch	September 1998
Various local agencies voice concerns and opposition to land acquisition prior to the completion of comprehensive studies	September/Oct 1998
CALFED rejects $14.5 million funding request by USBR due to local opposition	October 1998
USBR extends project timeline by 18 to 24 months due to local opposition	October 1998
USBR meets with Friant Users Authority and Oversight Committee	October 1998
Freedom of Information Act request is filed	December 1998
Madera County Supervisors pass groundwater ordinance and resolution opposing project	March 1999
Landowner sets deadline for USBR action	1999
Azurix purchases Madera Ranch site from landowner	October 1999

Institutional Arrangements

PARTICIPANTS

The proposed Madera Ranch Groundwater Bank Project sponsors and participants included Mr. Heber Perrett (owner), the USBR, SLDMWA, and SCVWD. Stakeholders included: local farmers and adjacent property owners; adjacent water and irrigation districts (Aliso WD, Gravelly Ford WD, Madera ID, Chowchilla WD); Madera County; City of Madera; California State Farm Bureau; Nisei Farmers League; Families Protecting the Valley; Tehipiti Chapter of the Sierra Club; Friant Water Users Authority; and the Regional Council of Rural Communities.[154]

The Phase 1 Report recommended that the choice between the two options that were under consideration—a multi-year lease of services and facilities or the purchase of the land and development of the facilities by USBR—be based on stakeholder consensus, partnership agreements, costs, contract negotiations and other factors.[155] However, no contractual arrangements for the use of the project were ever developed because the proposed Madera Groundwater Bank Project was not implemented beyond the Phase 1 Report recommendations.

BENEFICIARIES

As originally proposed, the water would be used to meet Central Valley Project (CVP) contract deliveries to agricultural water districts, as well as requirements to reduce pumping demands on the Delta to benefit wildlife refuges. USBR also proposed using the bank to implement a 100,000 acre-foot reserve account for drought relief in critically dry years. The non-federal project partners, the SLDMWA and SCVWD, participated in the project investigation to determine if possible banking opportunities existed for their agencies. Other potential uses included meeting unforeseen environmental needs and meeting general storage needs south of the Delta during certain critical periods.

STAKEHOLDER AND PUBLIC PARTICIPATION

According to stakeholder interviews, the Phase 1 Report, and other documentation, stakeholder participation during the preliminary investigation stage and the Phase 1 Investigation was limited to USBR, the property owner and the participating agencies (SLDMWA and SCVWD).

USBR issued a press release at the start of the Phase 1 Investigation to inform the public and identify interested stakeholders.[156] The press release was followed by the distribution of an information package to interested parties. Two public briefings were held and a list of interested parties compiled based on the telephone response to the press release and attendance at the public briefings.

Project Opposition

The Madera Ranch Groundwater Bank Project drew opposition from a variety of sources, most notably area farmers, local irrigation and water districts, Madera County and the City of Madera. The issues that triggered local concerns are summarized below:

> 1) Incomplete Information — opponents of the project characterize it as an example of USBR "getting the cart before the horse." Local stakeholders felt that the technical studies were very preliminary and incomplete, and thus the feasibility of the proposed project was not demonstrated sufficiently for policymakers to commit public funds to the project.[157,158,159] Some feel that the property owner's deadline for USBR action forced a premature commitment by the agency to move forward on the purchase of the property.[160] A Freedom of Information Act request for project information was filed by project opponents and Representative George Radanovich in 1998.[161,162] This request produced USBR internal documents and documents from other federal agencies that indicate potential flaws in the project as proposed.
>
> 2) Lack of Effective Public Involvement — due to the nature of the proposal, it was felt that USBR's public outreach came too late in the process and that local experts should have been consulted before, or at least during, the preliminary investigation. Utilizing local knowledge of the geography, aquifer response and historic water levels could have been beneficial to the evaluation. Additionally, CALFED officials and DWR Bulletin 160-98 characterized the project as feasible and beneficial before the technical studies were completed. As a result, the project was championed in several political arenas prematurely. This reinforced local concerns that the proposed project was political rather than technical in nature and a "top-down" driven project.[163] Community relations for the proposed Madera Ranch Groundwater Banking Project were a significant problem and local opposition is cited as the major factor in USBR's decision to abandon the project.[164,165]
>
> 3) Location near surface waters — the Madera Ranch Groundwater Bank Project site is in close proximity to the San Joaquin River, and adjacent property owners have observed immediate impacts to the unconfined aquifer based on fluctuations in the river levels. A 31.9-foot rise in water levels was observed over a twelve-month

period that included flooding and continuous river flows.[166] Based on these observations, local opponents to the project questioned the estimated storage capacity of the aquifer in the Madera Ranch area. Finally, the gradient and proximity to the river also raised concerns about a "topped off" aquifer and the outflow of stored water to the river.

4) Root Zone Flooding — local farmers adjacent to the Madera Ranch site have calculated that the area directly under the project site could only store a maximum of 130,000 acre-feet of water based on their observations of the variation of water levels in adjacent wells. Based on this calculation, the projects proposed storage of a maximum of 390,000 acre-feet would require about 10 square miles of surface area. Thus, local opponents believe stored water could move off of the project site, creating root zone flooding problems for neighboring orchards and other sensitive crops.[167]

5) Water Quality — Water quality consequences of groundwater banking were a concern for local farmers and adjacent landowners and were identified in the Phase 1 Report as an issue to be studied in the Phase 2 Investigation.[168] Local farmers state that the salinity of the Mendota Pool is approximately six times that of area groundwater; thus the introduction of Mendota Pool water might degrade water quality in the aquifer. This, coupled with the potential for stored water to move off-site, is a concern for farmers with wells and crops adjacent to the Madera Ranch site.[169] These concerns were echoed in comments by other agencies reviewing the preliminary studies, as evidenced in documents that were obtained by the Madera Ranch Oversight Committee through the Freedom of Information Act request referenced previously.[170]

6) Risk of Hydrologic Impacts on Groundwater Users — Proposed project well sites were upgradient of the infiltration ponds and close enough to the City of Madera wells that there was significant likelihood that water extracted may not be the water that was placed in storage. There was concern that the project could "exchange" lower quality banked water for higher quality native groundwater through the extraction process.[171] Additionally, area landowners were concerned about the accurate monitoring of the proposed project and its potential for extracting native groundwater in addition to the banked water (more "take" than "put). It should be noted that these hydrologic issues were expressed in communications by USBR staff, as evidenced in the Freedom of Information Act documents.[172]

7) Potential Loss of Local Control — the proposed project could present a means for outside interests to gain access to native groundwater and potentially other surface water entitlements (for example Friant water). In essence, local interests were concerned that the project represented a means for an outside entity to establish a foothold, or "pipeline," into the local water supply.[173,174,175]

Environmental Review

The CEQA process was not initiated for the proposed Madera Ranch Groundwater Banking Project. CEQA/NEPA compliance was to have been addressed in late 1998, according to the original project schedule. The Phase 2 Investigation would have identified whether or not a single CEQA/NEPA document would suffice for environmental compliance (as opposed to separate CEQA and NEPA documents).

The USBR Phase 1 Report indicates that the unfarmed area of Madera Ranch is "Priority 1" habitat "where actions must be taken to prevent the extinction or to prevent a species from declining irreversibly in the foreseeable future."[176] A reconnaissance survey of the site revealed the presence of vernal pools and the presence of sensitive terrestrial plant communities. Several species of halophytic (salt-tolerant) plants were found, and the presence or potential presence of several special status wildlife species was also noted.[177] Based on the reconnaissance survey, any groundwater banking facilities and operations at the Madera Ranch site would be required to minimize impacts on sensitive species and habitats. It should be noted that the reconnaissance survey in Phase I did not fully address the biological issues presented by the proposed Madera Ranch project and that additional site investigations would have been needed.[178]

Financial Characteristics

The options of leasing or purchasing the Madera Ranch were considered by USBR. The estimated cost of the proposed lease arrangement with Mr. Perrett was $14.8 million per year for a twenty year term. The option of purchasing the land was purported to cost from $43 million to $53 million.[179]

USBR estimated the annual cost for operations and maintenance of the facilities at $400,000. While the financing options were not fully developed, USBR did approach CALFED for $14.5 million to supplement the cost of purchasing the Madera Ranch site.[180] The Phase 1 Report identifies costs, cost allocations and repayment as items to be analyzed in the Phase 2 Investigation. Based on the term of the lease, the estimated value of the water produced was $226 per acre-foot at an annual yield of 70,000 acre-feet. The estimated value of the water under the scenario in which USBR would own and operate the facility is not available.

Issues and Risks

The proposed Madera Ranch Groundwater Banking Project did not proceed much beyond the Phase 1 Report phase, and thus the operational and administrative mechanisms for dealing with areas of risk were not fully developed.

The operational rules for dealing with the hydrogeologic risks of losing stored water were not developed. However, this was a significant issue that would have needed to be thoroughly addressed, both technically and institutionally, before the project could have been implemented.

As stated in the Phase 1 Report, landowners in the area were concerned about the location of the put and take conveyance features and the acquisition process for rights-of-way. They were especially concerned about the potential for parcels being split by infrastructure and land takes.[181] This issue was deferred to the Phase 2 Investigation. It was too early in the process to consider precise alignments and design of the conveyance features.

Potential crop damage associated with manipulating groundwater levels was a major concern of adjacent landowners, especially those with crops that are sensitive to high groundwater levels. This is an issue that would require significant study and the development of operational rules to avoid potential problems.

Summary of Issues

News articles and interviews with participants identify the lack of early stakeholder involvement and a clear public participation process, failure to incorporate the critiques of other federal agencies into the public process, the lack of sufficient technical analyses, the issue of local control, and the landowner-imposed deadline for USBR action as the key factors in galvanizing local opposition to the Perrett/USBR Madera Ranch Groundwater Banking Project.

Public and Stakeholder Involvement

The Madera Ranch Groundwater Banking Project chronology above indicates that the USBR took a logical approach to responding to the landowner's proposal by performing a preliminary analysis for potential fatal flaws. This step provided the Bureau with an indication of whether or not the project concept was worth pursuing further. The Phase 1 Investigation and Report were the next logical "due diligence" steps for the USBR.

The Phase 1 Report states that it is the USBR's policy to include public participation in decision processes that lead to federal actions, and it outlines a basic public involvement plan that includes identifying USBR and stakeholder roles, defining decision processes, holding briefing events, issuing a call for project partners and producing project status reports.[182] This process appears to comply with the USBR's Directives and Standards for public involvement in Reclamation activities.[183] If this is correct, then why is public/stakeholder involvement identified as a significant problem for the Madera Ranch Groundwater Banking Project?

As one commentator has noted: "a public interaction program, or the lack thereof, is often the sole or major reason for the failure to implement a water program."[184] Establishing and maintaining early, continuous—and most importantly, two-way—communications between the public, stakeholders and the water agency, preferably starting on "Day 1" of the project, is an essential element for building consensus and a successful program.[185,186] Based on comments by the local stakeholders that they would have preferred that USBR had consulted with them about the project at the conceptual stage, it appears that defining and communicating with potential stakeholders during the preliminary evaluation period would have been helpful to the overall process.

Keeping the process open and transparent by keeping all information "on the table" to the extent possible (outside of privileged negotiations) is another important element for gaining public trust and for effective communications. This appears to have been a problem for the Madera Ranch Groundwater Banking Project, based on the documented concerns of other federal agencies obtained through the Freedom of Information Act request by stakeholders.

Technical Analyses

The technical analyses of the Madera Ranch Groundwater Banking Project performed by USBR were preliminary in nature and designed to assist the agency in making decisions regarding the feasibility of the project. The Phase 2 Investigation would have addressed several outstanding technical issues, including the significant questions of compatibility of surface water from the Mendota Pool with native groundwater and the response of the aquifer under project operations. The major criticism of the preliminary and Phase 1 technical studies is that they were not sufficient to support the decision to commit public funds to the project.

It appears that the landowner-imposed deadline for USBR to commit to the project or acquire the project site may have contributed to the impetus to move ahead without the benefit of further technical studies.

Issues of Local Control

Many irrigation districts in the central, southern and eastern parts of the San Joaquin Valley have established effective conjunctive use programs in which water from wet years is stored in underground aquifers for dry year use.[187] Conjunctive use programs are widely viewed as an effective means for extending water storage in California, and Madera County stakeholders have stated that they support groundwater banking.[188,189] This poses the question of why the Madera Ranch Groundwater Banking Project met with significant local opposition.

In addition to the issues of insufficient public and stakeholder involvement and the need for more technical studies, the issue of local control, or the lack of local control, appears to be a major factor in the opposition to the Madera Ranch Groundwater Banking Project. The issue of local control can be exacerbated by the California water rights system. California's system of water rights does not require filing and licensing or quantification to establish rights to groundwater. A user only needs to begin use by drilling a well and making sure that the groundwater use is continuous.[190] Therefore, the concept of connecting the local groundwater basin to the rest of the California water system through extraction wells and a canal greatly enhances the fears of local stakeholders that local control could be taken away in the future. This, combined with the question of monitoring the quantities of banked water, makes it evident that a new, major non-local user of groundwater (in this case, USBR) would be viewed with suspicion, especially if that user were proposing a major extraction well field. Finally, no local benefits were identified by the project proponents, giving local stakeholders no incentives to support the project. Based on this situation, it can also be assumed that local interests would view local groundwater projects, controlled by local district boards and providing benefits to the community, more favorably.

In March 1999, a groundwater export and banking ordinance was passed in Madera County, along with a resolution opposing the Madera Ranch Groundwater Banking Project. This ordinance put in effect a permitting process for any groundwater project within the county and states that no groundwater extracted in the county can be exported without a permit. The groundwater exportation and banking ordinance was a direct response to the proposed Madera Ranch Groundwater Banking Project.[191] Also, Madera County officially appointed a Groundwater Oversight Committee in this time period.

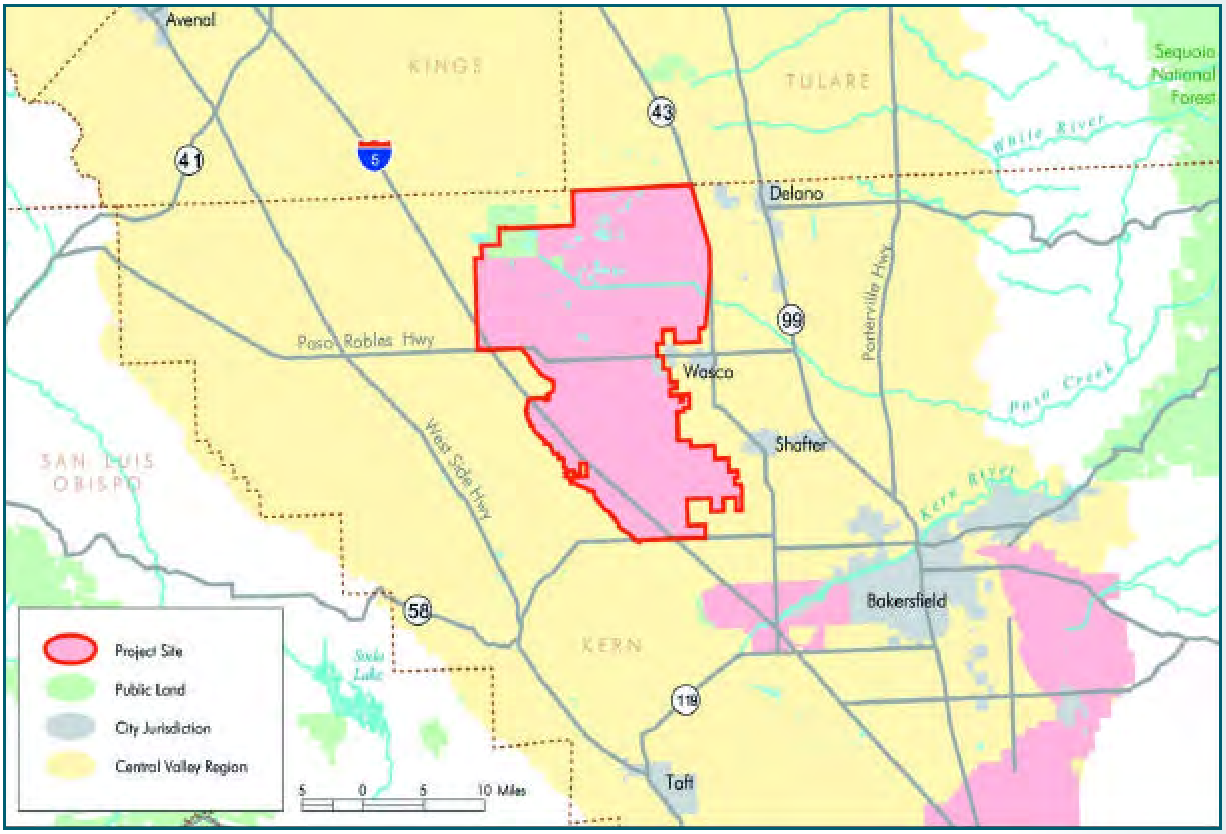
The concern over local control might have been effectively addressed through a public involvement process that established institutional and operational mechanisms to ensure local input and a measure of local control. As an example, an agreement could have been negotiated with Madera County to establish a stakeholder monitoring committee and set up enforceable operational rules for the project. This, coupled with an agreed-upon obligation to provide a quantity of banked water to alleviate conditions of overdraft, might have aided local support of the project proposal.

THE IMPORTANCE OF LOCAL SITE-SPECIFIC KNOWLEDGE

The subject of local site-specific knowledge is closely aligned with the issue of local control. Recent water policy research points out the need to integrate local site-specific knowledge with more generalized scientific understanding of hydrology in order to successfully address what one commentator called the "wicked water problems."[192] The assistance of people who work with and know the important site-specific factors that can impact a project must be effectively utilized when reviewing a project proposal. This need is clearly highlighted by the Madera Ranch Case.

In the Madera County setting, local farmers and water users with years of experience in using area groundwater and surface water are an excellent resource for evaluating the potential for a successful groundwater banking project. As cited in the section on local control, it is essential to involve these local experts in the initial project evaluation. It is recommended that local water organizations, in this case the irrigation districts, be used as a resource for engaging water users. These organizations often play a similar role interfacing between citizens, water users, and State and Federal agencies.

SEMITROPIC WATER STORAGE DISTRICT CONJUNCTIVE USE PROGRAMS



Introduction

This case study outlines the conjunctive use programs of the Semitropic Water Storage District.

Physical Characteristics

SETTING

Semitropic Water Storage District (Semitropic) contains 221,000 acres in the northern part of Kern County. Semitropic is surrounded on all sides by other water and irrigation districts including Lost Hills Water District, Buena Vista Water Storage District, Rosedale-Rio Bravo Water Storage District, Shafter-Wasco Irrigation District, North-Kern Water Storage District and the Southern San Joaquin Municipal Utility District.

HYDROLOGY

Semitropic is a primarily agricultural district that was originally developed with groundwater. The district has over 1,200 private wells. Continued use of these wells has caused significant overdraft in the basin underlying the district. To help alleviate this overdraft, the district started receiving surface water supplies in 1973 from the State Water Project. From 1973 to 1998 the district imported a total of 3,952,000 acre-feet of water. Other than its 155,000 acre-feet of State Water Project (SWP) entitlement (contracted through Kern County Water Agency) the district has no other significant surface water source. Rainfall is the district is also meager, averaging less than four inches per year.[193,194]

Of Semitropic's 221,000 acres, about 142,553 were irrigated before the district's groundwater banking program began. The "firm" contract surface water service area in the district compris-

es 42,343.65 acres and the groundwater service area in the district comprises 70,828.51 acres. An additional 29,381.99 acres has received temporary contract surface water service.[195]
Semitropic's total irrigation water demand exceeds 480,000 acre-feet per year, an amount greater than the district's SWP entitlement and other surface water supplies. Thus, the district still relies heavily on groundwater and the basin underlying the district is still in overdraft. In times of drought and/or minimal deliveries under its SWP contract (such as 1987–1992), the overdraft conditions in the district are severe and groundwater levels drop rapidly.[196,197,198]

Semitropic's Groundwater Banking Program began as a means of addressing several challenges that the district was facing in the late 1980s including an increasing groundwater overdraft, rising energy and water costs, and increasing unreliability of SWP contract water deliveries. The district sought a banking partner who was willing to finance such a program, with the goal that the additional money and facilities of the program would allow Semitropic to increase its own ability to take surplus waters when available, increase groundwater levels in the district, correct overdraft and reduce water costs to district landowners.[199]

Project History

Negotiations for Semitropic's banking program started in 1986 with Metropolitan Water District of Southern California (MWD). The Semitropic Groundwater Banking Program began as a Demonstration Project between the Department of Water Resources and the District. In 1990, the district and DWR entered into a contract, and DWR delivered 92,000 acre-feet of SWP water to Semitropic for underground storage via *in lieu* deliveries. The contract provided that the water would be returned to DWR via an exchange of the district's SWP entitlement wherein the district's landowners who would normally receive this SWP water would utilize groundwater substitution.[200]

In 1991, DWR wanted to recover its banked water by exchange of the district's SWP entitlement. Due to a very dry year and Delta pumping restrictions, no SWP water was available to the district that year, making the exchange impossible. These circumstances showed the District and others that a more successful groundwater banking program would include facilities to allow the district to directly deliver stored water back to the California Aqueduct, rather than having to rely on an exchange.[201,202]

MWD had been watching the DWR demonstration project in Semitropic with great interest and had been discussing a similar project with the district. However, in order for the project to be worthwhile from MWD's perspective, it had to include a pumpback component. While landowners in the district were originally apprehensive about this idea,[203] MWD and Semitropic started serious discussions and entered into a final banking agreement in 1994. Four additional Banking Partners have also contracted with Semitropic to participate in the banking program: Alameda County Water District, Zone 7 Water Agency, Vidler Water Company and Santa Clara Valley Water Agency.[204,205,206]

The basic concept of Semitropic's Groundwater Banking Program is that Banking Partners can purchase a proportionate share of the available space in the aquifer underlying the district by paying the district and delivering water to the district for storage. Banking Partners also pay to establish rights to use a proportionate share of the new facilities constructed to "put" water in storage and "take" it out at a later date.[207]

Engineering studies estimate that the basin beneath the district has at least 2,000,000 acre-feet of storage space.[208,209] To date, 1,000,000 acre-feet of space has been allocated between Semitropic's Banking Partners as follows: Metropolitan Water District of Southern California (MWD) 350,000 acre-feet; Santa Clara Valley Water District (SCVWD) 350,000 acre-feet; Vidler Water Company, Inc. 185,000 acre-feet; Zone 7 Water Agency 65,000 acre-feet; and Alameda County Water District 50,000 acre-feet.[210,211] These Partners have also allocated among themselves through contract the 91,000 to 315,000 acre-feet/year "put" capacity of the Program, the 90,000 acre-feet/year maximum pumpback capacity of the Program and the zero to 133,000 acre-feet/year maximum SWP Entitlement Exchange capabilities (for a total maximum "take" capacity of 233,000 acre-feet) of the Program. The source of water for the banking program consists primarily of SWP contract supplies of the Banking Partners.[212,213]

The percolation rates in the district are not high. Thus, water is banked via *in lieu* delivery arrangements with individual landowners. Banking Partners have financed the additional facilities necessary to expand this "put" capacity through fees paid when water is "put" in or "taken" out of the basin. The district has entered into individual contracts with landowners who receive *in lieu* water that specify how payment and operations will occur. Generally these contracts provide that the landowner will take *in lieu* surface water deliveries when made available from the district instead of pumping groundwater. These same agreements provide that the district may utilize the landowner's well (if it is not needed for irrigation of the landowner's property) to extract stored water for return to a Banking Partner, with full compensation.[214]

In 1999, the Banking Partners and Semitropic began studying an expansion of the original Semitropic Groundwater Banking Program that would increase the put and take capacity of the system so that full capacity of storage could be returned within a three-year period. This expansion plan was analyzed in a Draft and Final Supplement Environmental Impact Statement in 1999 and 2000 but has yet to be implemented.[215,216,217]

Institutional Arrangements

No new institutions were created to implement Semitropic's water banking program. Rather, the program operates through contractual arrangements between the banking partners, with surrounding landowners and with necessary agencies. These agreements are explained in detail below.

Financial Characteristics

Semitropic's Groundwater Banking Program is designed so that the district is fully compensated for the costs of construction and operation of the program by its Banking Partners. The Banking Partners' payments to Semitropic include the following kinds of payments: when water is stored; when water is returned from storage; with respect to energy used to recover water from the basin and deliver it to the Aqueduct; and for operation and maintenance expenses. The total cost to Banking Partners to store their supplies is approximately $175.00 per acre-foot (in 1994 dollars). Semitropic has structured the payments for Banking Partners so that there is an incentive to make larger payments upfront in order to achieve a permanent allocation of capacity in the system. These options are outlined in Table 4 on the following page.[218,219]

Table 4

*** All costs are in 1994 dollars, which began to escalate in 1995.*

	Option 1	Option 2	Option 3	Option 4	
Put	$110.00	$90.00			Per af in year water stored
Take	$20.00	$40.00	$10.00	$10.00	Per af plus actual power in year water is recovered
Annual O&M	$3.98	$3.98	$3.98	$3.98	Per af of vested storage capacity
Cycling Incentive	$20.00				Per af per year for water in storage longer than 5 years if capacity not vested
Capital Contribution			$12.40		Per af of storage capacity per year for the first 10 years
Capital Contribution				$120.60	Per af of storage capacity

Banking partners who use Option 1 have their capacity rights vested as water is put into storage. For those that use Option 2, storage and withdrawal capacity is specified at the outset and reserved during a ten-year vesting period. Only ten percent of total project capital is due within sixty days of signature. For those that want their storage and withdrawal capacity fixed at the outset, regardless of the amount of water stored in the initial years, Options 3 and 4 provide this benefit.[220]

The options outlined above apply to "first tier" water, or the amount of water required to establish capacity rights in the project. Recharge and withdrawal capacity rights are proportional to storage capacity rights. Once a banking partner has stored the amount of water represented by its specified storage capacity, any additional water put into storage is considered "second tier" and subject to a standard payment scheme.[221]

Interestingly, the banking agreements between Semitropic and its partners do not require that the district have the first right to use the new facilities constructed for the program. Rather, this first right is given to the Banking Partners for the duration of their banking agreements with the district. The district can use these facilities for its own operational flexibility, and to take surplus waters, when the facilities are not in use by the banking partners. The facilities will remain the property of the district.[222,223]

MWD advanced $1.35 million in early 1995 to Semitropic to begin design and construction of the banking facilities. In return, after the first five years of the Agreement, MWD is accorded a first priority to a certain storage capacity in the project. The "front-end" investment by MWD has been repaid through reductions in storage payments required under its banking agreement with the district.[224]

Issues and Risks

POLITICAL ISSUES

The district's President, Vido G. Fabbri, converted some of the landowners' original apprehension to a banking program with MWD into support through landowner meetings and a lot of "legwork". The district's General Manager, Will Boschman, was also instrumental in helping the district's board of directors and landowners visualize how the program would work. Before becoming the district's general manager, Mr. Boschman spent numerous years working for the Bookman-Edmonston engineering firm. The firm designed and constructed most of the water-related facilities in Kern County, including the recharge ponds and delivery system already in place in Arvin-Edison Water Storage District.[225]

In 1992, a temporary banking agreement was reached between MWD and Semitropic, which was converted into a long-term agreement in 1994. The agreement triggered CEQA, and an EIR was prepared in July of 1994. Surrounding landowners used the EIR process to address their concerns about potential third party impacts that a Semitropic Groundwater Storage Program might cause. Attorneys for Semitropic and the surrounding districts immediately started working together to resolve these concerns to gain the necessary support for the project. At the same time, districts adjacent to other new groundwater banking programs in Kern County were addressing the same concerns.[226,227,228]

Representatives of many of the affected parties had previously participated in a process to delineate the technical issues associated with the Kern Water Bank's groundwater monitoring program.[229] This process resulted in recommendations on rules to be incorporated in a Memorandum of Understanding between the project participants of the Kern Water Bank Authority and the Adjoining Entities, entered into in October of 1995, and for the MOU between Semitropic Water Storage District and the Adjoining Entities on September 14, 1994 (MOU).[230]

When the district and its Banking Partners proposed the expansion of the put and take capacity of the program in 1999, surrounding landowners again expressed their concerns through the Supplemental EIR process. Semitropic addressed these concerns by completing additional studies and maps as requested by the surrounding districts and by adding additional elements to its Mitigation Monitoring Plan as part of the Final Supplement EIR completed in January 2000.[231,232,233]

HYDROLOGICAL CONCERNS

The MOU for the Semitropic Groundwater Banking Project focused primarily on the hydrological concerns of surrounding landowners. The landowners were concerned about the following issues:

- Banked water would have recharge, evaporation and migration losses that needed to be accounted for to avoid withdrawal of more water than was actually banked.
- Groundwater migration could cause adverse impacts on groundwater quality or make it impossible to recover stored water, creating the risk that recovery of banked water would increase the pump lift for surrounding landowners.
- The placement and number of the extraction wells had to be planned so that the cone of depression around these wells would not adversely affect surrounding landowners dependent on groundwater.
- The program had to be closely monitored to prevent obstruction of natural recharge to the basin or an increase in basin overdraft.[234]

With these concerns in mind, Semitropic and the surrounding landowner districts hired Kenneth D. Schmidt, a groundwater quality consultant, to prepare a monitoring plan and detailed maps of "Well Location, Water Quality Network" and "Well Location, Water Level Network" that could be used as benchmarks for the monitoring program. In the meantime, the attorneys for the district worked on drafting the MOU. The primary elements of the MOU include the following:

- The MOU is based on the maximum project design as of 1994. Major changes or additions to this design are subject to additional environmental review.
- A monitoring committee, consisting of representatives from Semitropic and each of the surrounding districts and one ex officio non-voting representative of each of the Banking Partners, was created.
- A monitoring well network was established that would be modified as needed based on the committee's recommendations. Semitropic bore the cost of the installation of the original monitoring wells.
- Other costs of the monitoring program are borne 50% by Semitropic and 50% by the adjoining districts.
- "Fifteen-Foot/Three-Year Rule:" Semitropic will not make groundwater withdrawals that cause the average groundwater levels in an area to decline more than fifteen feet over a three-year period compared to the average groundwater levels that would have occurred without the project.
- If Project pumping causes well interference, Semitropic must stop pumping or compensate for the interference. The Monitoring Committee must establish criteria to determine if well interference is due to Project pumping.
- The MOU provides a dispute resolution procedure via the Monitoring Committee. If this procedure is not successful, any party may still pursue any remedy for injunctive relief or damages, with one exception. If all parties to the dispute agree that a factual dispute exists regarding any recommendation of the Monitoring Committee, the dispute shall be submitted to binding arbitration before a registered civil engineer with a background in groundwater hydrology. The MOU specifically states that nothing in the agreement prevents any landowners within the boundaries of any party from pursuing any legal remedy in the event the landowner is damaged as a result of the project.

Interestingly, the Semitropic MOU was the first finalized in Kern County between a banking district and surrounding districts. The Semitropic MOU was used as a model for the first draft of the more comprehensive MOU developed in 1995 for the Kern Water Bank, on direction by the Kern Water Bank Authority, and later to other Kern River Fan Projects.[235]

In addition to the MOU, The Final EIR approved by Semitropic and MWD under CEQA contains a Mitigation Monitoring Plan that addresses many of these same hydrological concerns and provides monitoring criteria for the project. The banking agreements between Semitropic and each Banking Partner also contain criteria to address hydrological concerns such as:

- Evaporation, migration and other losses for banked water are collectively assumed to be 10% of the amount of water furnished for storage. This loss percentage may be increased or decreased with evidence gained from monitoring.
- When water is returned via direct pumpback, it must be returned during Semitropic's off-peak irrigation season.
- Semitropic will seriously consider reducing or terminating groundwater pumping to return stored water to a Banking Partner if required by the MOU.[236,237]

To date, the Monitoring Committee has not had to resolve any disputes and no one has brought suit under the MOU or the Mitigation Monitoring Plans for either the original or Supplement EIRs for the project.[238,239]

ENVIRONMENTAL CONCERNS

From an environmental standpoint, implementation of Semitropic's Groundwater Banking Program has been relatively easy. The program does not utilize any natural stream systems or involve use of a significant amount of critical habitat. Environmental impacts identified in the 1994 EIR were mitigated pursuant to the Mitigation Monitoring Plan that was part of the Final EIR. In addition, the district was able to certify a Negative Declaration in May of 1996 that addressed the additional environmental impacts relating to the program that were not addressed in the 1994 EIR.[240] The district did not have to comply with NEPA because no federal agency approval is required to implement the program.[241]

WATER QUALITY ISSUES

The groundwater that is extracted for Banking Partners is delivered to them via the California Aqueduct. This required that Semitropic enter into an agreement with DWR for "Introduction of Local Water into the California Aqueduct." This agreement imposes strict quality criteria on the water that is introduced into the Aqueduct.[242] To date, the water withdrawn from Semitropic has met these criteria. If the criteria become more stringent, the water may have to be treated before it is pumped into the Aqueduct or returned via an exchange instead.[243] Any additional costs imposed due a change in water quality standards for the California Aqueduct must be borne by the Banking Partners pursuant to the Agreements between Semitropic and each Partner.[244,245]

Groundwater quality was one of the concerns addressed by surrounding landowners at the inception of Semitropic's program. To date, the program appears to have actually prevented the migration of lesser quality groundwater from west to east.[246]

Conclusions

To date, Semitropic's Banking Partners have stored over 675,000 acre-feet of water in the district. However, the only water recovered under Semitropic's program has been by DWR in 1992 and 1997.[247] Thus, the withdrawal capabilities of the program—and its potential third-party impacts—have yet to be tested.

From a financial perspective, however, the program has been very successful for Semitropic. The program will allow the district to finance $134 million worth of new facilities to increase its own operational flexibility. To date, over $70 million in new facilities have been constructed. In addition, revenue generated from Semitropic's banking program has, in part, allowed the district to reduce water charges to its landowners from almost $60 per acre-feet in 1995 to less than $50 per acre-feet in 1998. Pump lifts in the district have also decreased since the inception of the program by about 33 feet, representing additional savings in energy costs for landowners who utilize groundwater wells.[248]

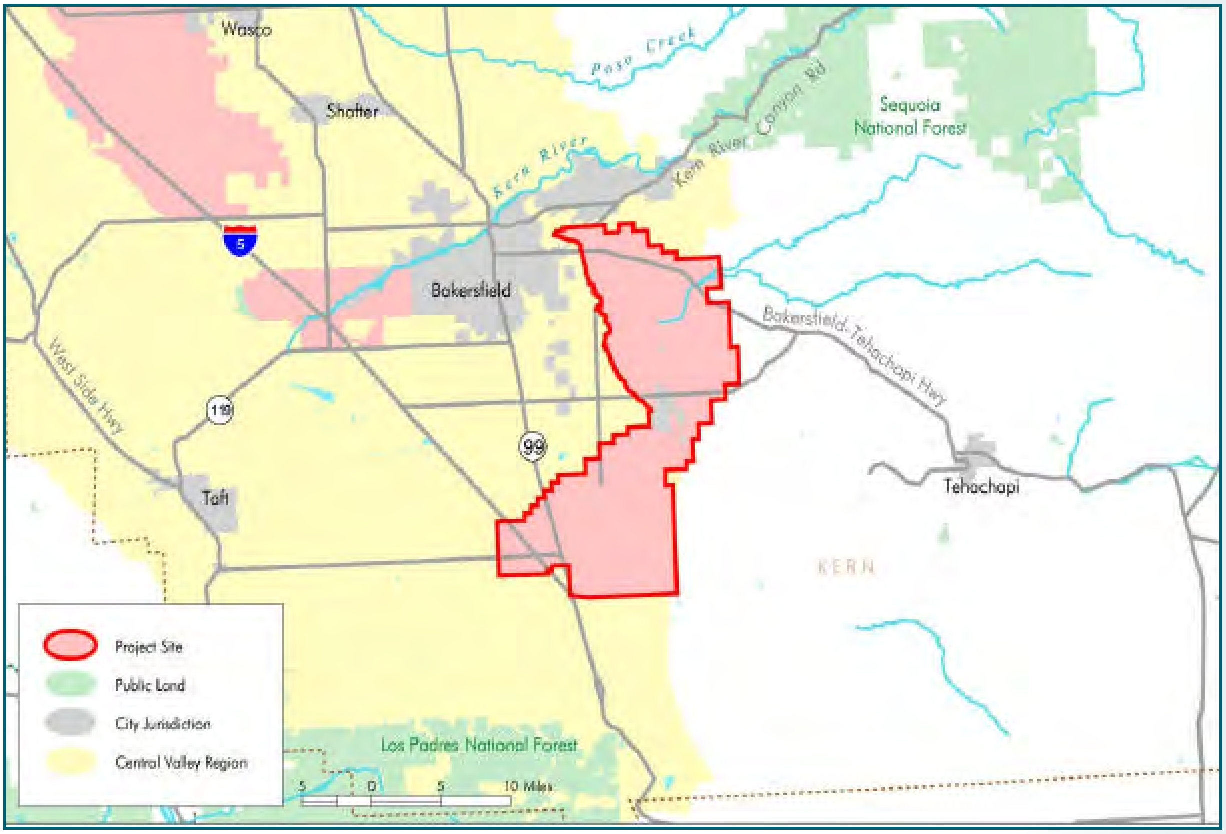
To date, the Semitropic Groundwater Banking Program has been successful due to the following factors:

- The program is not anticipated to affect the hydrogeologic conditions of a significant number of surrounding landowners.
- The landowners in Semitropic and surrounding districts that could be affected by

the program were generally cooperative in working with the district to resolve their concerns via a monitoring agreement and committee.

- The program was environmentally easy to implement.
- The district itself is a landowner-voting district where the larger landowners in the district are either represented on the board or trust those landowners who are board members. The banking Project was approved by a 97% favorable landowner election in November of 1991.
- The landowners in the district all have a common interest, as the district is primarily agricultural.
- The district has been in charge of the project since its inception and controls the operations in a manner that makes the landowners within and adjoining the district comfortable.
- Semitropic's Banking Partners have made the project essentially cost and risk free for Semitropic, while providing the district with numerous benefits and facilities.
- The district's general manager and president understood and supported the program and did a good job of explaining it to the members of the district and surrounding landowners.

ARVIN-EDISON WATER STORAGE DISTRICT CONJUNCTIVE USE PROGRAMS



Physical Characteristics

SETTING

Arvin-Edison Water Storage District (Arvin) consists of 132,000 acres in the southeastern corner of the San Joaquin Valley, entirely within Kern County. Arvin is bordered by the foothills of the Sierra Nevada on the east and the Tehachapi Mountains on the southeast. Farming began in the area now included in the district in the early 1900s. Today, the district is known for its high quality soils and high value crops such as grapes, citrus, potatoes, carrots, cotton, orchard fruit and truck crops.[249] The area is almost entirely agricultural, with only small areas of urban development.

HYDROLOGY

No significant streams or rivers are located within the district and the region receives only 8.3 inches of rain in an average year. Historically, farmers in Arvin relied primarily on groundwater to cultivate the region. Evidence of groundwater overdraft appeared as early as the 1930s. Prior to the importation of surface water to the area, depth to groundwater exceeded 600 feet in some areas of the district. In addition, the receding water table had induced the subsurface movement of water with high boron concentrations from the east into the aquifers underlying the district.

The district's groundwater basin can be divided into three distinct areas—a large central area and two smaller areas to the northeast and southeast. Two faults running through the district affect the movement of groundwater and create the three areas. However, in practice, the district is regarded as one groundwater management area.[250]

Project History

In 1942, the Arvin-Edison Water Storage District was formed to obtain a supplemental surface water supply in order to alleviate groundwater overdraft. The district secured Federal water contracts from the Central Valley Project (CVP) in the 1960s. In the meantime, agricultural operations expanded in the district, with approximately 100,000 acres in irrigated agriculture by the mid-1960s.

In 1966, the district began importing surface water from the Friant-Kern Canal under its CVP contract. A federal loan enabled the district to construct the Arvin-Edison Canal (which conveys water from the terminus of the Friant-Kern Canal into the district), 1,000 acres of spreading works, and 55 recovery wells. Thus, the district was able to store surface water underground via recharge ponds or by delivering surface water to landowners in lieu of their customary use of groundwater. To achieve economies of scale with the infrastructure, the district concentrated its surface water delivery facilities to serve 52,000 acres of the district with the poorest quality groundwater at the greatest depths. Thus, much of the district (about 80,000 acres) is still totally dependent on groundwater but has benefited from the district's programs in the form of reduced depth to groundwater (and associated reductions in pumping costs) and higher quality groundwater.[251]

The district's CVP contract includes 40,000 acre-feet of Class 1 priority water and 311,675 acre-feet of Class 2 priority water.[252] However, water deliveries under the contract are highly variable. Average demand for surface water in the district (exclusive of demand for groundwater) is 160,000 acre-feet. Deliveries under the contract have ranged from a low of 10,000 acre-feet in 1977 to a high of 351,675 acre-feet in 1978.[253,254]

The district has attempted to realize maximum benefit from its highly variable surface water supply, in part, through its conjunctive use system. The district deep percolates supply in excess of coincident irrigation demand when it can. The district has banked over 1.5 million acre-feet in this manner since 1966. The results are evident: in the 1950s, average overdraft in the district was 200,000 acre-feet per year; today overdraft averages only 5,000 to 10,000 acre-feet per year.[255,256,257]

Beginning in the 1970s, the district entered into exchange programs with other CVP contractors on the Friant-Kern Canal in an effort to further regulate its surface water supply. Through an exchange agreement, six exchange agencies located along the Friant-Kern Canal on the east side of the San Joaquin Valley receive up to 70,984 acre-feet per year of the district's highly variable Class 1 Friant water. In exchange, the district receives up to 66,096 acre-feet of non-Friant CVP water from the California Aqueduct (west of the district) on an irrigation demand schedule. The water that Arvin receives via this exchange is available almost every year, as opposed to the district's much less reliable Class 1 Friant water. Delivery of water to the district via the California Aqueduct is made possible by the Cross Valley Canal, which connects the Arvin-Edison Canal to the Aqueduct.[258,259]

In the mid-1980s, the district sought financing for additional water banking facilities that would allow further regulation of its erratic surface water supply and increased water availability to district landowners. These additional facilities would allow Arvin to take more of its Class 2 CVP water, when available, and store the supply in the underground aquifer for subsequent recovery during high demand/low supply periods. Thus, the district sought a partner that would provide financial assistance for these additional facilities in exchange for temporary storage of water in the groundwater basin underlying the district. By the late 1980s, a tentative agreement had been reached with Metropolitan Water District of Southern California (MWD). Although that initial agreement was never implemented, the concept resurfaced again in 1995, and a final agreement for a Water Management Program between Arvin and MWD was signed in 1997.[260,261]

In this original proposal, the Arvin/MWD program required approval by the United States Bureau of Reclamation (USBR) for the transfer/exchange of the Delta-CVP water to MWD; by the California Department of Water Resources (DWR) for use of the California Aqueduct to wheel CVP water to MWD under MWD's SWP contract and by the State Water Resources Control Board (SWRCB) for amendment to USBR's Delta-CVP water rights permits to include portions of MWD's service area as a permitted place of use and for changed points of diversion. Originally, the CVP Water Users Association opposed the concept of amending the Delta-CVP water rights permits. However, Arvin and MWD were able to resolve issues through negotiation with other Delta-CVP users and by agreeing to seek a very limited permit amendment that would facilitate only the proposed project.[262,263]

Federal and State approvals required environmental compliance pursuant to the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA), and a joint EIR/EIS was prepared in 1992. Public and agency comments on the Draft EIR/EIS reflected concerns that the project would result in increased deliveries from the delta that would damage the estuary and adversely affect fisheries. Pumping restrictions in place at the time rendered delta deliveries to the west side of the valley extremely unreliable. Because of the increasing uncertainty of delta deliveries, MWD determined that it was only interested in pursuing a banking program that included the option of direct pumpback of banked water. Thus, the program as planned was abandoned for the time being, and the SWRCB change petition that would have amended the Delta-CVP water right permits was never filed.[264]

After shelving the original banking program concept with Arvin, MWD negotiated and entered into a banking agreement with Semitropic Water Storage District that included a direct pumpback component. The Semitropic/MWD program addressed the concerns of neighboring landowners through an agreement that placed operational criteria on the project to limit third party impacts and required a formal groundwater monitoring committee.[265]

In light of the success of the Semitropic/MWD project, Arvin and MWD reinitiated discussions and developed a project that included a pumpback component. Under this arrangement, MWD would deliver its SWP water to Arvin for subsurface storage. At some future date, Arvin would recover the water and deliver it to MWD via a new 4.5-mile pipeline intertie between the Arvin-Edison Canal and the California Aqueduct.[266]

Under the twenty-five year agreement with MWD, substantial new groundwater banking facilities were constructed in the district including 500 additional acres of spreading ponds, 15 new groundwater wells, and a 4.5-mile bi-directional intertie pipeline connecting the terminus of the district's canal with the California Aqueduct. Facilities are expected to cost approximately $25 million. It is anticipated that MWD will store a minimum of 250,000 acre-feet of water in Arvin within the first seven years. Maximum storage levels over the life of the program are not specified, but MWD cannot store more than 350,000 acre-feet of water in the district at any one time without amendment of the agreement by both parties. The new spreading grounds constructed for the project have the capacity to recharge 45,000 acre-feet per year. The recovery capacity of the project ranges from 40,000 to 75,000 acre-feet per year.[267,268] To date, MWD has banked water in the district but has not yet withdrawn water from the district.[269,270] The agreement characterizes Arvin as holding MWD's water in "trust" while the water is stored in the district.[271]

The restructuring of the project obviated the need for USBR to approve the transfer, as Arvin's CVP water was no longer involved. Without USBR involvement, NEPA compliance was not required, and the project had only to comply with CEQA. After the Monterey Agreement, the water rights held by the State of California for the State Water Project allowed off-stream storage. Thus, the proposed project was already an approved use under project partners' SWP contracts and only required ministerial approval by DWR for changes in points of diversion. The parties adopted a Mitigated Negative Declaration in July of 1996, and the project was approved without substantial public or agency controversy. The agreement between Arvin and MWD for a Water Management Program was signed December 19, 1997.[272,273]

Currently, source water for the banking program includes only MWD water from its SWP contract and other sources. However, the Arvin/MWD agreement also contemplates acquisition and banking of 150,000 acre-feet (over twenty five years) of Friant flood flows as an additional source of water for MWD.[274] This aspect of the Arvin/MWD program was sought by MWD as an incentive to invest the many millions needed to construct the additional conjunctive use facilities in Arvin. It was also the most controversial part of the program.[275]

Friant flood flows are currently available to all Friant contractors. However, because they are available in times of very low demand and most districts do not have the facilities to capture and store the water, flood flows are not often utilized. The Arvin/MWD Agreement provides for flood flow purchase by Arvin for storage and transfer to MWD.[276] Theoretically, this transfer would have required that the Friant CVP water right permits be amended to add portions of MWD to the permitted service area. Other Friant water users and districts adamantly opposed the idea of expanding the permitted place of use to include MWD, fearing that MWD's domestic water uses would take priority over the needs of east side farms in times of shortage in the Friant system.[277]

This opposition led to negotiations between the Friant Water Users Authority, the Central Valley Water Coalition, MWD and Arvin.[278,279] The result of these negotiations was a Principals Agreement between the four groups that allows MWD to capture 150,000 acre-feet of additional water supply without the need to amend the Friant CVP permits. The Principals Agreement allows Arvin to purchase flood flows in the form of "Conservation Credits." Arvin can transfer these flood flows to Kern County Water Agency (KCWA) in exchange for a like amount of KCWA's SWP water which, in turn, can be sold to MWD and stored in Arvin's underground aquifer. MWD can request return of its stored water and the SWP water would be pumped back to MWD via the California Aqueduct.[280]

The concerns of the Friant Water Users and Central Valley Water Coalition were addressed by imposing specific operational criteria on when "Conservation Credits" may accrue and when water may subsequently be delivered to MWD. Under the Principals Agreement, Conservation Credits accrue to the extent that Arvin's new water banking facilities can conserve additional water supplies at times and under conditions that do not adversely affect other Friant Water Users. Thus, if Arvin shows that its new facilities can conserve up to 45,000 acre-feet of water per year, Arvin accrues 45,000 acre-feet of Conservation Credits and may transfer up to 45,000 acre-feet of non-CVP water to MWD.[281]

The Principals Agreement also explains that Conservation Credits can only be accrued if the following conditions are met:

- Water is being released from Friant Dam for flood control and can be diverted without unreasonably affecting downstream water quality requirements;
- Capacity exists in the Friant-Kern Canal, above all other demands for water delivery which will be used in the San Joaquin Valley, to deliver the water to Arvin; and
- The new water banking facilities in Arvin are recharging water.[282]

The Principals Agreement also requires that no land be fallowed for the purpose of transferring water outside of the San Joaquin Valley. These requirements provide protection to other Friant water users.[283]

The agreement expressly prohibits Arvin from delivering CVP water directly to MWD, which would have necessitated adding MWD as a place of use under the CVP water right permits. Thus, to put this component of the program into place, the additional exchange described above is required. MWD has also agreed that it will not pursue any future program involving Friant Division contract supplies that is inconsistent with the Principals Agreement without the prior written approval of the Friant Water Users Authority.[284]

Although Arvin and MWD made great strides in negotiating a solution to the opposition of the Friant Water Users Authority to this portion of their banking program, it is still not operational. This component of the program has been stalled by the USBR's interpretation that the contemplated transaction involving the conservation credits and subsequent transfer of non-CVP water to MWD would require the $25 per acre-foot M&I surcharge provisions of the CVPIA.[285] The negotiated Principals Agreement conditions the transfer to MWD on USBR approval of the long-term exchange/transfer, and on the exchange/transfer not being subject to the CVPIA. To date, USBR has stated that the transfer is subject to the CVPIA (notwithstanding that CVP water would be delivered to KCWA, which is not a CVPIA transfer), and that the $25 per acre-foot surcharge would apply. Because of this additional cost, the parties have not yet pursued this component of the project.[286]

Arvin intends to expand its banking program to third parties in the future, but no final agreements have been reached to date.[287] The MWD/Arvin Agreement contemplates such program expansion, however, and grants MWD certain rights of priority to banking and conveyance capacity in the new facilities.[288]

Institutional Arrangements

No new institutions have been formed to implement Arvin's banking program with MWD. Rather, the districts have formed the program through contractual arrangements between the districts themselves and between the districts and the Department of Water Resources. Negotiated principles with local interest groups have been used to overcome initial apprehension about controversial aspects of the program. For example, the contract between MWD and Arvin incorporates the Principles of Agreement between the district, MWD, the Friant Water Users Authority and the Central Valley Water Coalition. The contract between MWD and the district also requires certain monitoring activities and rules that are designed to protect local groundwater users.

Financial Characteristics

As noted above, the district's original facilities were constructed with a federal loan, which has since been repaid. The Arvin/MWD agreement provides that the $25 million to construct the facilities for the project will come from fees charged by Arvin to MWD for banking its water. Arvin will also recoup all of its costs through operation and maintenance fees, energy cost fees and conveyance facility use fees. The bottom line cost to MWD is about $250 per acre-foot.[289,290]

To finance construction of the necessary facilities, MWD advanced the district $12 million in fees. To recoup this investment, MWD will pay proportionately reduced rates per acre-foot when it stores and extracts water—in effect creating a $12 million interest-free loan from MWD to Arvin.[291,292]

Arvin is further protected financially because the agreement with MWD requires a minimum of 277,778 acre-feet of water to be stored by MWD in the district within seven years. This minimum level is tied to the estimated cost of facilities to be constructed so that the fees paid at this level will generate sufficient funds to pay for the cost of the necessary facilities. The Agreement contemplates that additional water may be stored by MWD, up to 350,000 acre-feet at any one time, upon mutual agreement of the parties. The parties may also amend the agreement to exceed this limit.[293,294]

Arvin's cash flow position in constructing the project is further protected in that MWD has agreed to advance additional funds to Arvin under certain conditions. Specifically, if at any time Arvin has expended $3 million more in constructing the necessary facilities than it has earned in water management fees, MWD will advance additional funds so that Arvin is never more than $3 million "upside down."[295,296,297]

The facilities constructed for the project are owned and operated by Arvin and allow the district the benefit of being able to increase its dry year supplies, expand its surface water delivery capabilities to additional acreage and increase its overall operational flexibility. Notably, the additional facilities that Arvin will own as a result of its banking program with MWD will allow the district to conserve about 8,000 to 10,000 acre-feet of its own contract entitlement per year. However, at an estimated cost of $25 million, it never would have been cost effective for Arvin to build these same facilities without the financing of a banking partner such as MWD.[298] MWD's use of the facilities will always be subject to Arvin's superior right to use the facilities for its own benefit. However, MWD will have a first priority to use a certain capacity of the new facilities in front of other bankers that enter the program in the future.[299]

MWD is responsible for dealing with DWR to schedule deliveries of returned water from Arvin to MWD via the California Aqueduct. Thus, MWD must incur the costs of these arrangements and meet the water quality standards necessary to put the returned water into the aqueduct.[300]

The financial risk that the project will not succeed has been primarily placed on MWD. There are several reasons why it could become impossible for Arvin to return stored water to MWD, including changes in water quality or water quality standards or other reasons beyond its control. If this were to happen, Arvin could buy the water that MWD has stored. The purchase would be arranged so that Arvin would buy the water from MWD for an amount equal to the costs that Arvin would have incurred to purchase the same amount of water as Class 2 supplies from the Friant-Kern Canal, under its contract with USBR in the year that the water was delivered to storage by MWD.[301]

Issues and Risks

POLITICAL ISSUES

Arvin's local benefit program Political opposition to Arvin's internal conjunctive use program has been non-existent. Notably, Arvin is a district that was originally formed to conduct conjunctive use operations for the benefit of its own landowners. Thus, the concept of conjunctive use and/or groundwater banking was never new or foreign to landowners in the district. Rather, those landowners surrounding the district's original spreading ponds and collection wells historically have experienced fluctuating pump lifts due to the district's operations.[302,303] Political opposition to Arvin's new banking program with MWD has come primarily from outside of the district and has not prevented implementation of the program.[304,305,306]

When MWD and Arvin first began negotiating a banking program in the 1980s, the district's consultants, attorneys and board members anticipated political opposition to any program that included pumping groundwater from the valley and conveying it to MWD.[307,308] Therefore, the program was structured so that MWD would receive its banked water only via exchanges on the California Aqueduct and never through a direct pumpback from the district. As originally envisioned, the proposal would have worked as follows:

- MWD would bank water in Arvin by delivering surplus water under its State Water Project (SWP) contract to Arvin for either direct recharge or delivery to farmers *in lieu* of groundwater pumping. MWD would accrue a like amount of groundwater credits.

- Recovery of banked water by MWD would involve transfer by Arvin of a portion of its Delta-CVP water received via the California Aqueduct (from the exchange agreement with the Cross Valley Contractors) to MWD. MWD would take delivery of water from the California Aqueduct that would otherwise be diverted at the Cross Valley Canal for use by Arvin. Farmers in Arvin would pump groundwater in place of the CVP surface water they would normally receive. MWD banking credits in Arvin would be reduced accordingly.[309,310,311]

HYDROLOGICAL CONCERNS

The concerns of adjoining landowners were addressed rather easily in the Arvin case. The only adjoining district affected at all by Arvin's manipulation of the groundwater table is Kern-Delta Water District, located to the west of Arvin. None of Arvin's recharge ponds or wells are located near the boundary with Kern-Delta, and thus groundwater levels in the neighboring district are not affected by Arvin's operations. However, there is a slight gradient of groundwater movement west to east from Kern-Delta to Arvin, with groundwater levels higher in Kern-Delta. Over the long term, it is conceivable that Kern Delta's water levels could be affected by a concentration of pump-back operations in Arvin over a multiple year period. To alleviate this concern, Arvin worked with Kern-Delta to adopt groundwater monitoring and operational criteria that became provisions of the contract with MWD. Although these criteria do not establish a contract between Kern-Delta and Arvin and/or MWD, they do set up project operating parameters that are acceptable to Kern-Delta and that protect landowners within Arvin.[312]

The contract between Arvin and MWD also provides the following protections for the basin:

- MWD may only request return of water to the extent that there is water in its account balance.

- A 10% loss is imposed on all water banked under the program; i.e., to recover 250,000 acre-feet of banked water, MWD must deliver 277,778 acre-feet to the district.

- Return of regulated water by the district to MWD must not interfere with deliveries to the district's contract users or other "normal and customary uses" by the district of its available supplies. Water will generally be returned to MWD "off-peak" and will not compete with Arvin's need for dry year water.

- Arvin will reduce or terminate groundwater pumping for purposes of returning water to MWD as necessary to comply with the groundwater monitoring program and operating criteria discussed above.[313]

ENVIRONMENTAL CONCERNS

As originally envisioned, some parties were concerned that the Arvin/MWD project would cause increased diversions from the delta at times that would injure fish or water quality.[314] Restructuring the project to include a pumpback rather than an exchange alleviated these concerns. Endangered species concerns were raised with regard to construction of the 500 new acres of spreading ponds and ancillary facilities necessary to operate the project, however, these concerns were addressed through mitigation or otherwise resolved through the CEQA process.[315] No natural stream systems were utilized as part of the project, and the isolation of the Arvin groundwater basin makes hydrologic interaction a minor issue.[316]

The groundwater produced in the district currently meets the state standards necessary for water to be pumped into the California Aqueduct for transport to MWD.[317] The agreement also requires that water delivered to Arvin by MWD for storage meet specific quality criteria.[318] The project has raised groundwater levels, which has reduced the migration of boron concentrations from the eastern hills surrounding the district.[319] Should any water quality problem arise, the Agreement puts the burden on MWD to solve the problem with DWR.[320]

Conclusions

The Arvin/MWD project has to date only operated to bank MWD's SWP water in Arvin. The recovery aspect of the project has yet to be tested. The other components of the project, including the use of Friant water and/or exchanges with CVP water, have also yet to be finalized because of outstanding cost issues associated with implication of the CVPIA.

To date, Arvin has not experienced any adverse third party impacts as a result of its own conjunctive use programs or as a result of banking water for MWD. This is so even though Arvin resorted to significant groundwater pumping for its own use during the late 1970s and early 1990s.[321]

Arvin's own conjunctive use program appears to have been extremely successful since its implementation in 1966 for the following reasons:

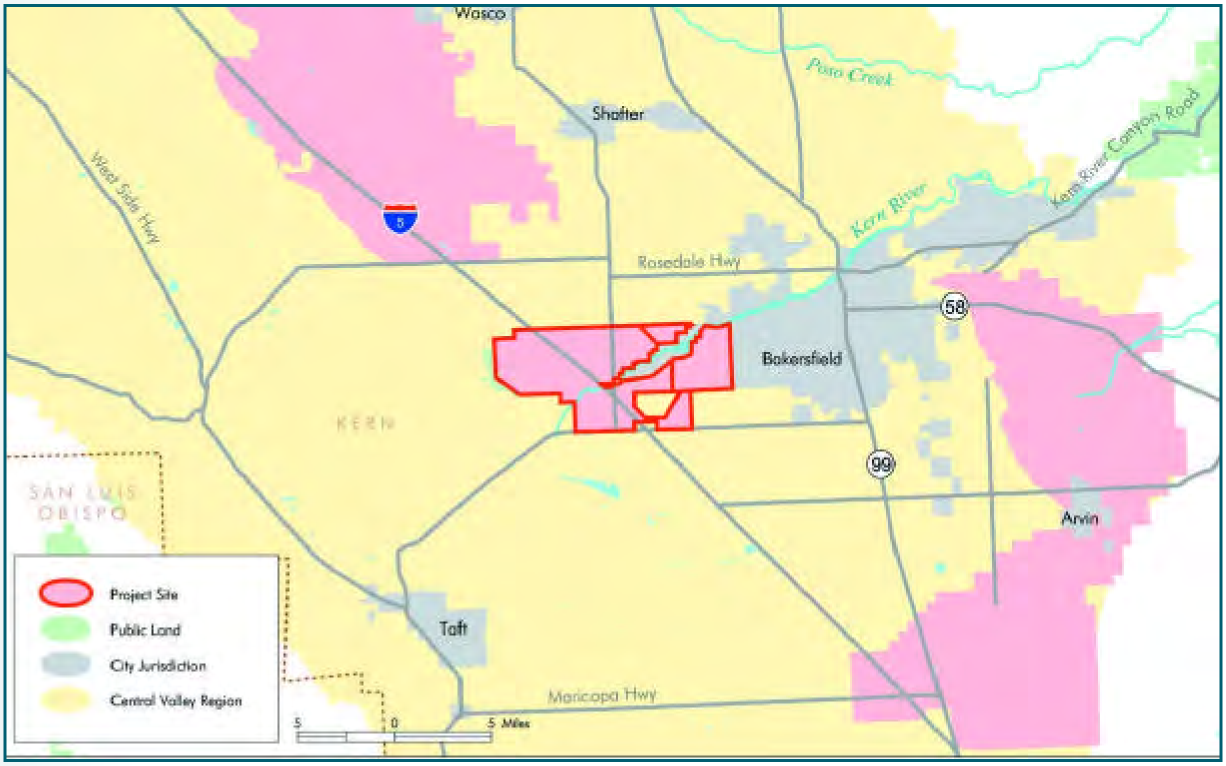
- Soils in the region are excellent for recharge ponds and have never had subsidence problems.
- Nearly half of all supplies banked in Arvin-Edison have remained to mitigate groundwater overdraft, and half has been extracted during critically dry periods.
- The program has had years of extreme pumping that greatly mitigated drought conditions without resulting in extreme impacts on pump lifts for surrounding landowners.
- The basin is relatively isolated geographically and does not interact specifically with surrounding basins or districts.

- History has shown that the program has resulted in a reduction in annual overdraft and much more plentiful and regulated supply of water for the landowners in the district.

Arvin’s project to bank water for MWD also appears to have been implemented in a rather painless fashion because of the following factors:

- The program will not hydrologically affect a significant number of surrounding landowners, if any.
- The landowners in the district are already familiar with conjunctive use and have seen it operate successfully in their district for almost fifty years.
- A board elected by the members governs the district whose votes are in proportion to their land holdings. Thus, the larger landowners in the district are either represented on the board or trust those landowners who are board members.
- The landowners in the district all have a common interest, as the district is primarily agricultural.
- The district has been in charge of the project since its inception and its control makes the landowners within and adjoining the district comfortable.
- USBR did not need to be involved in the project as currently approved.
- The project only had to comply with CEQA, not NEPA, and was able to be implemented with an Initial Study and Negative Declaration instead of an EIR or EIS.
- MWD was willing to make the project essentially cost and risk free for Arvin, while providing the district with numerous benefits.

KERN WATER BANK



Introduction

This case study reviews the Kern Water Bank (KWB) and provides an overview of the project development, interest group interactions, financing and performance. The KWB's objective is to enhance the water supplies of the southern San Joaquin Valley while providing exceptional upland and wetland habitat.[322] The beneficiaries include the KWB project participants, SWP contractors and Improvement District 4, which encompasses the City of Bakersfield located immediately east of the KWB site, the Rosedale-Rio Bravo Water Storage District immediately north of the site, and the Kern Delta WD to the south. The banked water is used primarily in agriculture.

Physical Characteristics

SETTING

The KWB is located on 19,883 acres of land in Kern County, California, at the extreme southern end of the San Joaquin Valley. The Kern River flows through the southeastern portion of the site from northeast to southwest. The KWB is on the lower part of the Kern River Fan.

The primary land use in the vicinity is agriculture. Approximately 835,000 acres of irrigated land exists in Kern County.[323,324] The SWP and the Friant-Kern Canal, linked by the locally-constructed Cross Valley Canal, serve the area. The City of Bakersfield is located to the east of the KWB site and is the major municipal water user in the area.

Approximately half of the 19,883 acres of the KWB project area has been set aside for habitat as part of the KWB Habitat Conservation Plan. More than forty species of birds have been sighted at the KWB, including the Caspian tern, white-faced ibis, and freshwater pelicans.[325] ESA listed species found on the KWB site include the San Joaquin kit fox (Vulpes macrotis mutica), Tipton's kangaroo rat (Dipodomys Tiptonsi), and blunt-nosed leopard lizard (Gambelia sila).[326]

HYDROLOGY

Groundwater pumping in the area serves agricultural and municipal uses. Median groundwater use for irrigation is 1.2 million acre-feet per year, while drought year use increases to 1.9 million acre-feet per year. In 1998–1999, the City of Bakersfield, with a population of over 210,000, used approximately 59,511 acre-feet of groundwater per year to meet its annual water demand of 73,500 acre-feet.[327] The balance of its demands are met by treated surface water supplied by Kern County Water Agency, KCWA.[328]

Bakersfield owns and operates a 2,800-acre groundwater recharge project that follows the path of the Kern River through the easternmost portion of the Kern Water Bank site. In addition, the Kern County Water Agency Pioneer Project recharge areas (North Pioneer, Central Pioneer and South Pioneer) are adjacent to the KWB on the east and northeast. Neighboring water districts include the Rosedale-Rio Bravo WSD immediately north of the KWB site and the Kern Delta Water District and Wheeler Ridge-Maricopa WSD located to the south of the site.

A unique combination of water supply, delivery infrastructure and geology place the KWB in an ideal location for water banking. The KWB can take advantage of water deliveries from three sources—the Kern River, the California Aqueduct (State Water Project), and the Friant-Kern Canal.[329] The Kern River and the California Aqueduct converge near the KWB, and the Kern River is the terminus of the Friant-Kern Canal, which is a facility of the federal Central Valley Project (CVP).[330]

The KWB is located in the Tulare Lake Hydrologic Region, which has an aquifer system with the capacity to store an estimated 50,000,000 acre-feet of water.[331] As a sub-section of the Tulare Hydrologic Region, the 19,883 acre KWB has the ability to store an estimated 1,000,000 acre-feet of water at an estimated annual recharge capacity of 450,000 acre-feet per year.[332] The recovery capacity is estimated to be 240,000 acre-feet per year at project completion.[333]

Approximately 7,000 to 7,200 acres of the KWB are used as active recharge basins.[334] There are 61 shallow (2 feet deep) recharge basins at the site, with approximately 63 miles of levees.[335] The areas between the recharge basins are managed as habitat. The habitat areas are approximately 6,800 acres and are used to regenerate native grasses and plants to provide habitat for local threatened and endangered species. Additionally, the water recharge process has created intermittent wetlands, with willows and tules growing at the edges of the recharge basins, thus providing habitat for a variety of waterfowl.[336]

The Kern River (winter floodwaters) and the SWP are the major sources of water banked in the KWB. The location of the KWB also allows for delivery of water from the Friant-Kern Canal. Construction of a six mile long, two-way conveyance canal connecting the SWP and the Kern River to the KWB was initiated in August 1999.[337]

The water is banked in what is known as the Kern Fan Element. This river fan consists of sandy soil created by years of alluvial deposits. KFE sediments are capable of percolating up to six inches of water per day. Recharge is accomplished utilizing 800 cubic feet per second (cfs) flow from the Kern River and 750 (cfs) from the SWP (California Aqueduct).

Banked water will be recovered by thirty new recovery wells and fifteen old wells that have been rehabilitated. These are located on the site, and an additional thirty wells are proposed as part of the KWB Master Plan Facilities. Other Master Plan Facilities include: a two-way canal connecting the KWB and the SWP; approximately 21 miles of transmission pipeline; and a 545 cubic feet per second (cfs) pump station and meter structures.[338,339] As of August 2000, the two-way canal, turn-outs, pipeline and meter structures were nearly complete.[340]

The new two-way canal will have a capacity of 800 cfs. Drilling started on thirty new extraction wells during 2000 and eighteen existing wells were slated for rehabilitation.[341] Recovery is anticipated to be 375 cfs (240,000 acre-feet per year) to the SWP. [342]

Project History

The original proposal to bank water at the KWB dates to the 1970s when Tenneco West, Inc., the owner of the land where the KWB is now located, and the Wheeler Ridge-Maricopa WSD entered into an agreement to explore banking water on the 46,000 acre Tenneco West parcel. Wheeler Ridge-Maricopa WSD recognized that the scope of the proposed project would require the participation of other entities and began to solicit potential partners in the Kern County area. However, most districts and entities in the Kern County area looked to the completion of the State Water Project (SWP) for additional water supplies and, therefore, chose not to participate in the Wheeler Ridge-Maricopa/Tenneco West project.[343] As a result, Tenneco West eventually terminated the agreement with Wheeler Ridge-Maricopa WSD. Subsequently, Tenneco West sold the future KWB land to the Department of Water Resources (DWR) in 1988, as discussed below.[344,345]

By the early 1980s it became apparent that the SWP would not be completed as anticipated. Consequently, in years of short water supplies in the SWP, water contractors in Kern County receive substantially less water from the SWP than their initial expectations.[346] As a result, a groundwater overdraft of approximately 250,000 to 300,000 acre-feet per year persisted in Kern County.

Thereafter, a series of technical studies, such as "Water Resources Management in the Southern San Joaquin Valley California (1979)" and the "Report on the Investigation of Optimization and Enhancement of the Water Supplies of Kern County (1983)," illuminated opportunities to integrate available surface water supplies into groundwater recharge operations. The reports also underscored the adverse impacts of continued groundwater overdraft in Kern County. These factors, combined with the opportunity to increase SWP water supply reliability during dry years, provided the incentive for DWR to initiate the KWB project in 1988 with the purchase of 19,883 acres of the Tenneco West property.

With that acquisition, DWR phased out farming leases on the KWB land. In 1991–1992, the California Department of Fish and Game identified endangered species on the fallow land, and it became subject to Endangered Species Act requirements.[347] Subsequently, DWR's process of developing the KWB project stalled due to high costs, habitat regulations, complicated negotiations over local use of the bank and uncertainty over the volume of water that could be diverted from the delta for storage.[348,349] The estimated cost of banked water was approximately $400 to $450 per acre-foot, which was unacceptably high for local users.[350] Over $28 million was spent on proposal studies without any project development.

In 1990, local water district managers formed the Kern County Future Water Supply Committee to evaluate future water supply options including groundwater banking in the southern Kern area.[351] The Committee was spurred along by the prolonged drought from 1987 to 1992, which resulted in significant impacts to SWP water users in Kern County. Reductions in SWP allocations and major increases in groundwater pumping for local use and export during 1990–1991 underscored the need for the KWB project. In 1992, an Issues Resolution Committee was appointed to produce a draft set of rules for the joint operation of the KWB and to resolve monitoring issues.

The existing KWB project (under the Kern Water Bank Authority) was initiated on August 4, 1994, when DWR staff, Kern County Water Agency staff, and representatives of the Westside Mutual Water Company met to discuss the potential for transferring the KWB property from DWR to Kern County interests in exchange for 40,000 acre-feet of SWP annual entitlement. Subsequently, representatives of the State Water Contractors and DWR executed the Monterey Agreement ("Statement of Principles for Potential Amendments to the State Water Supply Contracts") on December 4, 1994. The Agreement established principles for making changes in the SWP water supply contracts by modifying each contractor's SWP contract.[352] The Agreement allowed for an amendment to local SWP contracts that facilitated the exchange of the KWB lands from DWR to Kern County Water Agency and Dudley Ridge Water District in return for 45,000 acre-feet of SWP entitlement.[353] Subsequently, DWR agreed to allow the KWB project participants, under Kern County Water Agency, to use the KWB in April of 1995.

After the execution of the Monterey Agreement, Kern County Water Agency, Dudley Ridge WD, Semitropic WSD, Wheeler Ridge-Maricopa WSD and the Westside Mutual Water Company agreed to a Statement of Principles for the Development, Operation and Maintenance of the Kern Fan Element of the KWB. This group, with the addition of the Tejon-Castaic Water District, became known as the Project Participants.

By the end of 1995, the Project Participants had formed the Kern Water Bank Authority (KWBA), executed a "Memorandum of Understanding Regarding Operation and Maintenance of the Kern Water Bank Groundwater Banking Program," established a Monitoring Committee with non-participating districts adjoining the KWB to ensure avoidance or mitigation of potential adverse impacts resulting from KWB operations, and executed a transfer and exchange agreement for the transfer of the KWB from the Kern County Water Agency to the Kern Water Bank Authority. Thus, in 1995, the KWB officially became a locally operated project under a joint powers authority formed for the purposes of recharge, storage, and recovery of water to supplement State Water Project supplies to agricultural and urban communities within Kern County.[354]

Prior to the transfer of the KWB from the Kern County Water Agency to the Kern Water Bank Authority, the KWB Project Participants had received a 2081 Permit from the California Department of Fish and Game for interim operation of the KWB and a Section 7 Permit from the U.S. Fish and Wildlife Service (USFWS) for interim operations. KWB participants began recharge operations with floodwaters in 1995 under an emergency declaration to prevent flooding (Kern County Water Agency operated the KWB facilities for project participants). This declaration expedited the USFWS permit process and freed the Water Agency from California Environmental Quality Act (CEQA) compliance requirements. Environmental effects of recharge with regulated non-emergency flows were addressed in an adopted mitigated negative declaration.[355] By the end of 1995, over 222,000 acre-feet of water had been recharged into the KWB.[356]

On August 9, 1996, the KWB property was officially transferred from the Kern County Water Agency to the Kern Water Bank Authority. In 1997, the KWBA filed a CEQA Notice of Determination and completed the 75-year KWB Habitat Conservation Plan/Natural Community Conservation Plan. Construction of Master Plan Facilities, consisting of a six mile long, two-way conveyance canal connecting the SWP and the Kern River to the KWB, turnout facilities on the SWP and Kern River, 30 new recovery wells, 15 rehabilitated recovery wells, approximately 21 miles of transmission pipeline, and metering structures, commenced in 1999. During the 1995–2000 period, the KWBA recharged a total of 871,502 acre-feet of water into the KWB, nearly reaching the 1,000,000 acre-feet of estimated banking capacity.

The chronology of significant KWB project events, up to and following the Monterey

Agreement, is summarized below:[357,358]

1986 — DWR begins to explore the possibility of developing a Kern Water Bank for the purposes of augmenting the SWP.

May 1986 — DWR issues a draft program Environmental Impact Report (EIR) on the proposed KWB.

December 1986 — DWR issues the Final Program EIR.

March 1987 — DWR enters into a memorandum of understanding with the KCWA to develop and operate the KWB.

April 1987 — DWR issues a Preliminary Technical Report describing the features, facilities, costs, and operation of a direct recharge program.

August 1987 — DWR accepts a report from a consultant evaluating toxics in the area of the Kern River Fan.

September 1987 — DWR makes an offer to Tenneco West, Inc., to purchase approximately 24,000 acres of Tenneco West land for the purposes of establishing the KWB.

May 1988 — DWR contracts with the Kern County Water Agency to assist in the development of the KWB. DWR and the Water Agency solicit proposals from local districts to participate in the KWB. Seven local districts express interest in participating; DWR and the Water Agency analyze the proposals.

August 31, 1988 — escrow closes on the purchase of 19,833 acres of Tenneco West land by DWR. The land is purchased by DWR for $31,115,168.74 (approximately $1,565 per acre).

1989 — DWR installs monitoring wells and implements water level and water quality monitoring program. DWR starts the five-year phase out of 20 agricultural leases on approximately 16,000 acres of the KWB land. Planning activities for the KWB are implemented by DWR. Land management activities are started, as is the clean up of contaminated soils.

1989 through 1994 — DWR spends approximately $28–$30 million on studies. ESA issues emerge. Participants note that the cost of banked water is increasing to around $400 to $450 per acre-foot already with no physical banking project yet in place.

1990 — Kern County Future Water Supply Committee is established and provides the forum for discussion of operating criteria for banking projects in Kern County.

1991 — drought impacts begin to underscore the need to move ahead with the KWB. Agricultural allocations of water from the SWP are reduced to zero acre-feet, and municipal and industrial users are reduced to 35 percent of their allocation. Exportation of groundwater out of the Kern area basin accelerates.

1991 — due to lack of water, 101,400 acres in the entire San Joaquin portion of Kern County are fallowed; 9,700 acres are abandoned after crops (primarily, cotton and almonds) are planted; and 101,700 acres of crops suffer reduced yields.

August 1992 — Kern County Future Water Supply Committee appoints an Issues Resolution Committee for the purpose of identifying resolutions to issues surrounding the monitoring and operations of a joint water bank project.

1993 — SWP contractors and the DWR enter into negotiations to resolve dry year water allocation issues.

August 4, 1994 — DWR staff, Kern County Water Agency Staff and representatives of the Westside Mutual Water Company meet to discuss the potential for transferring the KWB property from DWR to Kern County interests in exchange for 40,000 acre-feet of SWP annual entitlement.

August 22, 1994 — the Issues Resolution Committee issues its Draft Groundwater Management Rules. Attorneys Committee begins to investigate the formation of a Joint Powers Authority to operate the KWB.

October 6, 1994 — the Issues Resolution Committee issues a memorandum describing six major areas where disagreements remain regarding the Groundwater Management Rules for banking projects.

December 1994 — the Monterey Agreement between the DWR and the SWP water contractors is executed to resolve dry year allocation issues. This agreement sets forth principles for making changes in SWP water contracts, which would be implemented by amendment. The Monterey Agreement allows for an amendment to the Project Participants contracts to allow the title to the Kern Water Bank to be transferred to local SWP contractors in exchange for 45,000 acre-feet of their annual SWP entitlements. The Kern County Water Agency is to assume operation of the bank.

March 1995 — the Kern County Water Agency, Dudley Ridge Water District, Semitropic Water Storage District, Wheeler Ridge-Maricopa Water Storage District and the Westside Mutual Water Company agree to a Statement of Principles for the Development, Operation and Maintenance of the Kern Fan Element of the Kern Water Bank.

April 13, 1995 — DWR agrees to allow KWB participants use of the Kern Water Bank for water banking, with the Kern County Water Agency managing operations until the Kern Water Bank Authority is officially chartered in October 1995.

May 16, 1995 — California Department of Fish and Game (CDFG) issues a 2081 Permit for the interim operation of the Kern Water Bank.

May 22, 1995 — U.S. Fish and Wildlife Service (USFWS) issues a Section 7 Permit for Stage 2 1995 Interim Operation of the Kern Water Bank.

May 1995 — the KWB Project Participants start recharging water at the KWB.

June 27, 1995 — USFWS and CDFG meet with KWB participants regarding the outline for the Habitat Conservation Plan and to discuss master permit and Natural Communities Conservation Program issues.

October 16, 1995 — Project Participants officially form the Kern Water Bank Authority, which incorporates prior participant agreements.

October 26, 1995 — a Memorandum of Understanding Regarding Operation and Maintenance of the Kern Water Bank Groundwater Banking Program (MOU) is entered into between the Project Participants in the KWB and the Adjoining Entities (agencies not participating in the KWB). This MOU addresses and resolves the six major issues identified by the Issues Resolution Committee. The Monitoring Committee is established.

December 13, 1995 — the Transfer and Exchange Agreement between the Kern County Water Agency and the Kern Water Bank Authority is executed. Upon close of escrow, this agreement will allow the transfer the KWB property from the Water Agency to the Kern Water Bank Authority.

December 31, 1995 — a total of 222,377 acre-feet of water is recharged into the KWB.

August 9, 1996 — the KWB property is transferred from Kern County Water Agency to the Kern Water Bank Authority.

June 4, 1997 — Kern Water Bank Authority posts CEQA Notice of Determination.

October 2, 1997 — signing ceremony takes place for the completion of the KWB Habitat Conservation Plan.

August 30, 1999 — construction is started on the KWB Master Plan Facilities, including a two-way canal, 72,000 feet of transmission pipeline, a pump station, and new recovery wells to allow an estimated recovery of 236,430 acre-feet of water per year.

April 2000 — 871,502 acre-feet of water has been recharged into the KWB.

August 2000 — most of the Master Plan Facility construction is complete. Installation of new recovery wells and distribution piping are the major facilities remaining to be completed.

STAKEHOLDERS AND BENEFICIARIES

Participants in the KWB (referred to as Project Participants) include: Dudley Ridge Water District, KCWA, Semitropic Water Storage District, Tejon-Castaic Water District, Westside Mutual Water Company and Wheeler Ridge-Maricopa Water Storage District. Project Participants entered into a Joint Powers Agreement to form the KWBA.

Additional stakeholders include: Rosedale-Rio Bravo Water Storage District, the Buena Vista Water Storage District, the Henry Miller Water District, the West Kern Water District and the Kern Delta Water District. These agencies are not participants in the KWB, but, due to the proximity of their agency boundaries to the KWB, they are stakeholders. The special districts listed above (referred to as "Adjoining Entities") entered into a Memorandum of Understanding with the KWBA regarding the operation and maintenance of the KWB so as to prevent significant adverse impacts and to create a monitoring committee and forum for dispute resolution.

Paramount Farming Co., a major landowner and farming operation in the area, is another stakeholder. Paramount Farming Co. played a key role in working with DWR and the participants to facilitate the transfer of the KWB land from DWR to the Kern Water Bank Authority.[359] The Kern County Water Agency acted as the intermediary in the transfer of the KWB land to the Kern Water Bank Authority.

Outside agencies can purchase KWB water from Project Participants per the JPA. The JPA contains a "right of first refusal" clause, wherein a Project Participant proposing to transfer (sell) water must first notify the other Participants of the offer and allow them the opportunity to purchase before selling to a third party.[360,361] KWB recently concluded one-year sales of water to USBR for 70,000 acre-feet and the Westlands Water District for 45,000 acre-feet of water.

It should be noted that the KWB project priority is to enhance water supplies for the KWB project participants and SWP contractor needs (when possible). Kern County Water Agency member units and the Kern County Water Agency have a second priority.

Project Opposition

The Adjoining Entities had six concerns regarding the KWB that needed to be resolved before an agreement to proceed could be reached. These issues were as follows:[362]

- The level of authority of an oversight committee (Project Participants say it functions as a forum and for record keeping; Adjoining Entities propose authority power to modify programs for compliance with groundwater management plans).
- The right to reserve the recharge capacity of the basin for local water supplies (avoidance of reduction in the capability of the basin to recharge both imported and native water).
- Recognition of the possible benefits to the basin (bankers would like recognition of enhancements to the basin due to banking).
- Recognition of mitigation credit for fallowed land (adjoining entities propose no credit, Project Participants propose a credit).
- Definition of adverse impacts to prevent recovery.
- Definition of migration losses.

Local water users' fear of adjudication was an incentive to develop an agreement to resolve these six major issues. A sixty day negotiation process resulted in the execution of a "Memorandum of Understanding Regarding Operation and Monitoring of the Kern Water Bank Groundwater Banking Program" between the Project Participants and the Adjoining Entities.

STAKEHOLDER AND PUBLIC PARTICIPATION

The KWB project engaged local stakeholders through the Future Water Supply Committee process and the Issues Resolution Committee process. The Kern Water County Agency represents many of the water agencies in the area, as they are member units of the Agency. This helps to provide some cohesiveness among the stakeholders. Public participation was accomplished through the environmental compliance (CEQA) process.

ENVIRONMENTAL REVIEW

The original Environmental Impact Report for the KWB was completed by DWR in December 1986 for the purpose of acquiring the Tenneco West land (Final Environmental Impact Report, Artificial Recharge, Storage and Overdraft Correction Program, Kern County, California—Kern Water Bank). The EIR adequately analyzed potential operations of the KWB and identified potential groundwater impacts, in this case interference with neighboring banking projects. Monitoring and rotating recharge areas to minimize impacts was recommended. It should be noted that the issue of endangered species at the site was not identified until 1992.[363] A mitigated negative declaration was issued in 1995 to address recharge operations utilizing non-emergency regulated flows.

Financial Characteristics

As mentioned earlier, the KWB was purchased from the DWR through an entitlement transfer. Major construction costs for the KWB project were obtained through a Proposition 204 loan ($5 million) and a private loan ($20 million).[364]

The expenses for the operation and maintenance of the KWB for FY 2000–2001 are budgeted at $1,645,100. These expenses include the cost of monitoring, operations and maintenance, land management and administration. Income to the Kern Water Bank Authority from banking operation assessments, mitigation credit sales, grazing, third party banking and interest earnings is estimated to balance with the budgeted expenses.[365]

Monitoring costs via the KWB Monitoring Committee are shared equally between the KWB Project Participants and the Adjoining Entities.[366] Costs for construction of monitoring wells are borne by the project participants. Each of the parties is responsible for the personnel costs of their representatives to the KWB Monitoring Committee.[367]

The costs of operations and maintenance for the KWB are recovered by the Kern Water Bank Authority through assessments levied against the Project Participants per their share of the project.[368]

The KWB project water uses the market value of water to establish the base value of the water put into storage.[369] Thus, in 2000, the value of the water was approximately $138 per acre-foot, based on recent transactions with the USBR and Westlands Water District.[370] However, it should be noted that the value of water is dependent on the hydrologic cycle, and the cost of $138 per acre-foot would be more typical of the minimum cost or "value" of KWB banked water.

The price of water to third parties outside of Kern County could be in the range of $350 to $400 per acre-foot, depending on variable costs.[371]

Issues and Risks

Hydrogeologic risks are addressed in the 1995 "Memorandum of Understanding Regarding Operation and Monitoring of the Kern Water Bank Groundwater Banking Program (MOU)." This MOU creates a Monitoring Committee made up of one representative from each of the Adjoining Entities and one representative from each of the Project Participants. The Monitoring Committee oversees a comprehensive monitoring program to determine groundwater levels and water quality under project and non-project conditions. The Monitoring Committee has the authority to retain an independent expert consultant to assist in the data collection and analysis necessary for monitoring the banking operation. The Monitoring Committee, assisted by the consultant, prepares a monitoring plan, maps well locations and specifies additional monitoring wells as needed for a monitoring network. The consultant prepares annual water balance studies, develops criteria to define excessive groundwater mounding, and develops recommended KWB Project operating criteria for the purposes of avoiding significant adverse impacts. The Monitoring Committee deals with all banking projects operating in the Kern Fan Area and is the body charged with resolving disputes regarding the KWB Project operations. Meetings of the Monitoring Committee are held monthly or at regular intervals as deemed necessary.

The MOU states that the banking project will be operated by the "golden rule," meaning that, unless acceptable mitigation is provided, the banker may not operate so as to create conditions that are worse than would have prevailed absent the banking project. Also, the MOU states, "operators of projects in the Kern Fan area will avoid operating recharge projects in such a fashion so as to significantly diminish the natural, normal and unavoidable recharge of water native to the Kern Fan Area as it existed in a pre-project condition."[372] Per the MOU, mitigation measures for hydrogeologic risks include the following:

- A spread-out recovery area and the provision of adequate well spacing.
- Buffer areas between recovery wells and neighboring overlying users.
- Limits on the monthly, seasonal, and/or annual recovery rate.
- Provision of sufficient recovery wells to allow the rotation of recovery wells.
- Adjustment to pumping rates and/or termination of pumping to reduce impacts.
- Time restrictions between recharge and recovery to allow for downward percolation of water to the aquifer.
- Provision of water that would not otherwise be available to recharge the Kern Fan Basin.
- Lowering of well pump bowls or deepening wells for impacted overlying users.
- Provision of alternative water supplies to impacted overlying users.
- Financial compensation to impacted overlying users.

The MOU assigns losses of water during the recharge process at 6% for evapotranspiration, and 4% for migration. Thus, the assigned loss rates help to dedicate water to the basin for overdraft correction. Finally, the operation of the recharge basins is deliberately designed to create intermittent wetlands to provide habitat for waterfowl.

CONVEYANCE CAPACITY

Conveyance capacity in the SWP (California Aqueduct) is conditioned through a Point-of-Delivery Agreement. Put and take conveyance is accomplished in accordance with a schedule approved by DWR. A Use-of-Facilities Charge is applied for each reach of the California Aqueduct in which the users are not participating in a repayment of charges.[373]

GROUNDWATER RIGHTS

Recovery has not preceded recharge due to the fact that the KWB may only recover water that it has recharged. With regard to protection of banked groundwater, the monitoring program described above provides such protection, as it is composed of the adjoining agencies that utilize groundwater in the Kern River Fan.

WATER QUALITY

The 1995 "Memorandum of Understanding Regarding Operation and Monitoring of the Kern Water Bank Groundwater Banking Program" provides for water quality monitoring and has specific requirements for the operation of the KWB to enhance water quality. Recharge water must be of high quality and cannot degrade the groundwater basin.

Financing is allocated by the percentage of base shares of the Project Participants, and operating costs are pooled and shared in a similar fashion. Using the base share formula, the costs are allocated as follows:

Table 5

Agency	Percentage Share of Costs and Benefits Based on Entitlement Contributed
Kern County Water Agency	9.62%
Dudley Ridge	9.62%
Semitropic	6.67%
Tejon-Castaic	2.00%
Westside	48.06%
Wheeler Ridge	24.03%

POLITICAL RISKS

The political risks associated with adverse community reactions for this project are minimal because:

- Water banking projects are common in the area and tend to be accepted as required to preserve and enhance the economy of the area.
- The KWB project has done an effective job of creating habitat and enhancing the natural environment.
- The Monitoring Committee structure offers a forum for addressing the concerns of overlying users adjacent to the project.

Conclusions

KWB participants cited the following factors as having contributed to the success of the Kern Water Bank:

- Kern County has a long history of water banking programs; therefore, it is not a new concept but rather considered a "tried and true" method for water resources management.

- The water agencies within the southern Kern County area are fairly cohesive. The Kern County Water Agency serves as an umbrella organization and a forum for water agencies dealing with the DWR on SWP contracts. The Water Agency also serves as an important intermediate "linking" and resource organization for representing local interests at the state level.

- Leadership within the local water interests recognized the need to develop committees or other mechanisms to reach out and include stakeholders in the program development process. The "glass house" theory was used extensively—in other words, invite and include as many participants into the project as possible (they are less likely to "throw stones" if they are involved in the project).

HYPOTHETICAL ARRANGEMENTS

Based on the lessons learned from the case studies, we propose the following design features for successful and locally acceptable conjunctive use projects. These elements are posed for detailed discussion and reaction by focus groups comprised of knowledgeable and constructive groundwater users, water managers, local officials and opinion leaders in the communities that appear on the basis of hydrogeologic criteria to be particularly well-suited for groundwater banking. The Natural Heritage Institute intends to conduct such focus group reviews as a future phase of the "System-Wide Investigation of the Opportunities for Conjunctive Water Management in the Central Valley" project, out of which this case study report itself emanated.

OVERALL PROJECT DESIGN:

- Banked water would be imported. Thus, aquifer would be actively recharged with water not otherwise available;
- Recharge and extraction facilities would be sited within an existing water district service area or within an AB-3030 planning area;
- The banking operations (recharge and recovery) would be performed by (under the control of) the overlying water district or groundwater management authority;
- Local benefits in the form of water or cash payments would be obligated in enforceable contracts. These commitments could take the form of rights of first refusal in favor of the local water district or authority that is operating the bank (or its individual members) to utilize either the banked water or the aquifer storage capacity or both;
- For unincorporated areas (e.g., for *in lieu* projects), create a local water management authority by special act or county ordinance; and
- Issues, alternatives, and mitigations would be routinely analyzed in NEPA/CEQA documents with full public participation.

IMPROVEMENTS IN HYDROGEOLOGIC INFORMATION

- Measures to improve baseline data in the project area would be undertaken. Local groundwater users would be included in the process of collecting, interpreting, and modeling the data. Efforts would be made to prompt DWR to aggressively improve aquifer baseline information in the areas most suitable for banking.

HYDROLOGIC ASSURANCES

- "Groundwater substitution" projects would only be conducted where subsequent recharge is assured—perhaps through escrow arrangements;
- *In lieu* banking would be conducted only where substitute surface water deliveries are assured—perhaps through escrow arrangements;
- Groundwater substitution arrangements and *in lieu* arrangements should be avoided in areas with shallow wells unless the project is operated within tolerance limits or it pays for deepening the wells or it provides a substitute water supply out of the bank to neighbors with shallow wells;
- The project would commit to recharge more water than it recovers by a specified percentage to provide a buffer against hydrogeologic uncertainties, or the

project would provide some other type of hydrologic assurance;

- The project would be operated within specific water table elevation limits to avoid inundating root zones or structures;
- The recharge and extraction facilities would be located near the center of the overlying water district of groundwater management authority to avoid or minimize effects on external groundwater users;
- The project would cease pumping or provide automatic compensation whenever monitoring wells indicate interference with neighboring wells. Where this potential is significant, the project would allow neighboring groundwater users to order cessation pending investigation of the impacts;
- The project would extract water on a schedule designed to avoid impacts on irrigators. The schedule could be subject to modification by the monitoring committee. For example, the extraction schedule would be limited to seasons or days when neighboring wells are not in operation such as nights, weekdays or before or after the peak irrigation season;
- The groundwater bank should be located as far as possible from surface streams (unless interaction is desired);
- The contract terms should assure that water deliveries to beneficiaries will cease at the termination of the contract period. Enforcement mechanisms might include export permits of limited duration or substantial liquidated damages; and
- Where recharge water is routed through the delta (or otherwise degraded en route), it will be subject to water quality criteria that will assure that the recharge water is of higher quality than the *in situ* groundwater.

FINANCIAL ASSURANCES

- Costs incurred by neighboring landowners due to increases in power requirements to lift groundwater—for any reason—will be compensated out of project revenues. Such compensation arrangements will feature streamlined and simplified claims processing procedures; and
- The customers of a groundwater banking project will defray the costs incurred by the water district or groundwater management authority that is providing the banking services even if delivery constraints beyond the control of such banker prevent the delivery of water to such customers. The customers may also be required to pay those costs in advance. If the banked water cannot be delivered, banking district can purchase that water at their marginal costs of substitute supplies.

LEGAL ASSURANCES

- In groundwater basins that are in a condition of chronic overdraft, groundwater users' historic rates and volumes of pumping would be immune from legal action by groundwater bankers. Unless the basin is adjudicated, the formula for defining "historic use" would be specified in the contract setting up the groundwater bank;
- In groundwater basins in which current extractions are less than natural recharge, groundwater users' would also be immune from legal action to the extent of the "safe yield" surplus in the basin. Unless the basin is adjudicated,

the formula for defining "safe yield" and surplus would be specified in the contract setting up the groundwater bank;

- For *in situ* projects, either all of the local groundwater users would be brought into the project via contract (probably unrealistic), or the program will have to be operated in a manner that avoids injury—perhaps by allowing "take" only after a period of "put"; and
- A groundwater banking project will have the burden of proving that its operations will not cause injury to legal users of water, including groundwater users, where the project is required to obtain a permit or order from the State Water Resources Control Board or a local groundwater management authority.

MONITORING PROGRAM

- A banking project will establish a groundwater monitoring program directed by committee representing the local groundwater users as well as project participants. The program will include perimeter monitoring wells and adequate monitoring infrastructure. The program will monitor specified quantity and quality parameters. The committee will possess the power to modify the pumping regime when specified thresholds are exceeded; and
- The committee will also be vested with authority to resolve disputes regarding project operations either directly or by referring the dispute to an arbitration panel comprised of technical experts.

LOCAL PARTICIPATION

- The overlying water district or groundwater management authority that will provide the banking services will consult with the local groundwater community, involve it in the project design and operations, and solicit and use "local knowledge" of groundwater conditions;
- Where possible, the project will be located in areas where groundwater banking is already an established practice;
- The project proponents will make all technical investigations transparent and provide ample opportunities for early review and comment;
- The proponents will complete all technical investigations and public review before implementation steps are taken; and
- That will include thorough and convincing NEPA/CEQA compliance.

ENDNOTES

INTRODUCTION

[1] For the purposes of this paper, "imported water" refers both to "foreign water imported from a different watershed" or water that comes from an in-basin source that is not hydrologically connected with the banking site within a relevant period of time (e.g. flood flows of a river). City of Los Angeles v. City of San Fernando, 14 Cal. 3d 199, 261 n.51 (1975). Note that this definition would include water that originates within the same hydrologic basin as the banking site, provided that it would not be available for extraction at that site but for the physical act of bringing it to that location as recharge water.

[2] We use the term "rent" figuratively for, as we shall see in the section of this document on "Outstanding Issues", overlying landowners probably do not have a right to charge rent for the use of the subsurface aquifer. Nonetheless, the landowner or groundwater management entity that provides and operates the recharge and recovery facilities will want to participate in the benefits of the groundwater bank. When that inducement takes the form of a cash payment, it may resemble "rent", a term of art we employ with the above caveat.

[3] The potential for groundwater export and refill projects adversely affecting streamflows is a function of the transmissivity of the groundwater, the proximity to surface streams, and the interval between extraction and refill. These are parameters that are not difficult to control if the baseline information is adequate. We envision projects where extraction and refill both occur annually, and where the bank is located remotely from surface streams. Under those circumstances, uncertainties in the current understanding of the linkage between surface water and groundwater systems in the northern Sacramento Valley should not pose an unmanageable risk.

[4] The courts, using their equitable powers, and the State Board, though Cal. Wat. Code § 275, can fashion and enforce physical solutions to ensure more efficient use of water, provided that the legal rights of the parties are protected and senior rights holders are not required to incur any material expense. See generally City of Barstow v. Mojave Water District, 23 Cal. 4th 1224 (2000). (Examples of State Board enforcement of physical solutions include SWRCB Decision 1631 and Order WR 98-05, D 1600 and Order 88-20, and Orders WR 2000-13, WR 96-002, WR 94-2 & 93-8, and WR 90-16.)

SCOPE AND METHODOLOGY

[5] The storage of Friant flood releases at Arvin-Edison comes closest to the system-wide approach. However, it does not entail reoperation of Friant Reservoir to capture such flood events.

FINDINGS AND CONCLUSIONS

[6] E.g., the Semitropic and Arvin-Edison programs have allowed these districts to finance new facilities that increase their internal operational flexibility to the substantial benefit of the districts' members.

[7] The Kern Water Bank MOU includes the following provisions:

A spread out recovery area and the provision of adequate well spacing.
Buffer areas between recovery (extraction) wells and neighboring overlying users.
Limits on the monthly, seasonal, and/or annual recovery rate
Provision of sufficient recovery wells to allow the rotation of recovery wells.

[8] That monitoring committee prepares annual water balance studies, develops criteria to define excessive groundwater mounding, and develops operating criteria to avoid adverse impacts. It is also charged with resolving disputes concerning project operations.

[9] Personal communications with Madera County Groundwater Oversight Committee (Pistoresi and Prosperi) and Steve Ottemoeller, Madera Irrigation District, April 6, 2000.

[10] Stuart G. Walesh, *Dad is Out, Pop is In, 35:3* Journal of the American Water Resources Association, 537.

[11] USBR, Reclamation Manual/Directives and Standards CMP 04-01, http://www.usbr.gov/recman.

[12] Walesh, supra note 10, at 540.

[13] *Consensus Quells the Water Wars*, Sacramento Bee, April 29, 1999, Section Editorials, at B7.

[14] "Bank on it or Flush it?", Fresno Bee, July 2, 2000.

OUTSTANDING ISSUES

[15] See, e.g., Niles Sand and Gravel Co. v. Alameda County Water Dist., 37 Cal. App. 3d 924 (1974).

[16] Unless already authorized, groundwater banking usually involves both a new place of storage and a new or expanded place of use (when the water is pumped back out of the aquifer). The State Board exercises jurisdiction over both. See California Water Code § 1266, Cal. Code Regs. tit. 23, § 722.

[17] For instance, the groundwater banking authority must avoid raising the groundwater table to a level that might invade the root zones of neighboring crops or structures. It must avoid lowering the groundwater table below the level

that would exist in the absence of the project, thereby dewatering nearby wells or increasing the power requirements for pumping. The banking authority must also avoid degrading the quality of the *in situ* groundwater.

[18] For example, water users could be made whole through delivery of an alternate source of water of equal quality and quantity. Additionally, a well owner who has to deepen her well to respond to a declining water table (as occurs with a groundwater substitution project) might be reimbursed for the increased well construction and pumping costs. Depending on the nature and severity of the change, adverse impacts on groundwater quality may not be allowable even if the affected well owners accept compensation.

[19] By their terms, the county and watershed of origin statutes apply only to water that originates in the county or watershed of origin. However, if this water is banked within the county or watershed of origin and then extracted and exported, it would seem that the doctrines would apply.

[20] City of Los Angeles v. City of San Fernando, supra note 1.

[21] The importer would lose rights to the water only if it is abandoned, which would be contrary to the intent of a groundwater banker, or is acquired by "adverse possession", also known as prescription. Prescriptive rights cannot be obtained as against a public agency, however. City of Los Angeles v. City of San Fernando, 14 Cal. 3d 199 (1975). This is yet another reason why water districts are the preferred operators of a groundwater bank.

[22] The California Supreme Court has affirmed the paramount rights of the importer to recapture foreign water intentionally lost to groundwater basins and unintentionally lost to surface waters. See, Stevens v. Oakdale Irr. Dist., 13 Cal. 2d 343 (1939); City of Los Angeles v. City of Glendale, 23 Cal. 2d 68 (1943); City of Los Angeles v. City of San Fernando, 14 Cal. 3d 199 (1975). Some water law practitioners contend that the Stevens rule permitting recapture of unintentionally lost imported water should not be extended to deep percolation from irrigation. They are concerned that if the right to recapture percolation losses is extended to large importers like the SWP or CVP, they could effectively control every groundwater basin in the Central Valley. Others point out that groundwater users who are the incidental beneficiaries of irrigation imports contribute nothing to the capital or maintenance costs of such projects, and are not entitled to insist on the continuation of that gratuity.

[23] This issue is emerging in discussions over the reoperation of Friant Dam to restore the downstream anadromous fishery. The increased releases will increase infiltration in the Gravelly Ford reach. Groundwater pumpers in that area are likely to benefit from the increased recharge—if it is theirs to pump. Is a change in dam operations of this sort an act of importation, utilizing a natural channel to bring in water that would not otherwise be available to the aquifer but for the reoperation, if part of the intended purpose is to bank groundwater downstream? If so, shouldn't the USBR be entitled to pump that increased recharge and deliver it to, for instance, the San Joaquin exchange contractors in exchange for Mendota Pool water that could be wheeled to the Friant Water Users to make them whole? On the other hand, the Gravelly Ford groundwater users point out that that increased flow to more closely mimic the natural hydrograph is water that would have been available to them as recharge water if Friant Dam had not been built. Thus, the reoperation merely restores a degree of the natural conditions to which they are entitled. The issue of the hydrologic and temporal baselines for determining what constitutes "imported water" permeates this paper and is a matter on which we recommend clarifying legislation.

[24] Katz v. Walkinshaw overturned the rule of absolute ownership of groundwater traced back to Acton v. Blundell, 12 Mees. & W. 324 (Exchequer) (1843), and rejected the notion that a landowner owns everything from the "heavens to the center of the earth." It made groundwater a common property resource in that groundwater resources must be shared in a correlative fashion by the overlying landowners. But Katz did not consider whether an overlying landowner may restrict a water importer from using the free space in an aquifer.

[25] If overlying users own a correlative share of the aquifer storage space, they arguably would have to be compensated for use of that space, whether or not they are injured. The City of Los Angeles v. City of Glendale and City of Los Angeles v. City of San Fernando holdings make no provision for compensation for use of aquifer storage space.

[26] City of Los Angeles v. City of Glendale and City of Los Angeles v. City of San Fernando uphold Los Angeles DWP's importation and storage of water underground despite Los Angeles' status as an appropriator and lack of any statutorily authorized groundwater management authority.

[27] See Slater, California Water Law and Policy (1998); City of Los Angeles v. City of San Fernando, 14 Cal. 3d 199 (1943).

[28] Correlative rights are like riparian rights: they are neither quantified nor prioritized by historic use. The only limitation on their exercise is the mutual avoidance of harm. The problem that emerges is illustrated by the following hypothetical: Suppose a groundwater bank is recharged for two years and then water is extracted in the third year. Suppose there are three overlying groundwater users, A, B and C. In the first two years (of recharge), A and B greatly exceed their historic rates of pumping to take advantage of the new recharge, and in the third year they revert to historic levels. In that third year, the program also seeks to extract. The combined pumping increases C's lifting costs above the historic baseline. May C sue to prevent the project from extracting its water? May the project sue in the first two years to prevent A and B from increasing their rates of pumping?

[29] There is an enforcement problem, however. Water users are typically aware when pumping exceeds safe yield, but the costs of curtailing pumping and/or initiating an adjudication inhibit legal action for abatement. Also, an individual user has at least a theoretical argument that it can increase its pumping as its needs increase, even when the basin is in overdraft. The fact that total use exceeds the safe yield does not rule out the possibility that some of the overlying users are entitled to increase their pumping (i.e. their correlative share happens to be higher than their current pump-

ing, because their needs have substantially increased). See City of Barstow v. Mojave Water Agency, 23 Cal. 4th 1224 (2000). Of course, the total basin pumping cannot legally increase, but they could argue that others' correlative share must be reduced to accommodate their increased need.

[30] However, the fact that the land is within the boundaries of a district that delivers surface water doesn't necessarily mean that the district is doing anything to regulate groundwater extractions.

[31] Some water lawyers argue that the State Board has no jurisdiction over water in underground basins because it is not water flowing in "surface streams" or in "known and definite channels." The argument suggests that, once surface water is put into aquifer storage, it becomes groundwater outside of the State Board's authority to regulate. Also, county ordinances define "groundwater" subject to their jurisdiction as "all water below the surface not in known and definite channels."

[32] See, e.g., In the Matter of Application 17002, Decision No. D. 894, at 3 (Mar. 25, 1958)(approving an application for water that, after appropriation, will be placed into underground storage and later released for municipal, domestic, irrigation, and recreation purposes over 18,100 acres of land); In the Matter of Application 20621, Decision No. D. 1235, at 3, 29 (Aug. 25, 1965)(approving the Navy's application to store 4,000 afa underground from which it will be pumped for military, domestic, municipal, and agricultural purposes, both within and without the watershed.)

[33] For example, In the Matter of Application . . . to Appropriate Water from Sespe Creek In Ventura County, Decision No. D 1129 (Apr. 29, 1963), the State Board weighed competing permit applications for development of certain water resources in the Santa Clara River basin near Oxnard. The United Conservation District planned to appropriate water year-round for domestic, industrial, irrigation, and salinity control purposes, with a portion of the water first being placed in underground storage. In approving United's application, the board, as a condition of United's permit, held that it retained authority to ensure the use of the water was consistent with the permit. We note that these orders pertain to water right applications. It is not certain that the same holdings would apply to change orders.

[34] The ultimate use of the water is subject to the reasonable and beneficial use requirement of Article X, §2 of the California Constitution. Under Water Code §1242, the storage of surface water underground is considered a beneficial use if the water provided that the water so stored is thereafter applied to a beneficial purpose.

[35] The State Board retains authority over the use of water diverted from a natural watercourse even if it is first diverted to storage in an offstream reservoir. Its jurisdiction does not depend on whether the reservoir is characterized as a "natural channel" as long as the water diverted into the reservoir was diverted from a stream lake or other body of water. For purpose of State Board jurisdiction over rediversion and use of water first stored to a reservoir, the Water Code does not distinguish between surface and underground reservoirs. See California Water Code § 1201.

[36] California Water Code §§ 10750-10753.9.

[37] See California Water Code § 10753.8(c).

[38] The ten special districts are Willow Creek Groundwater Management Agency (Lassen Co.), Honey Lake Groundwater Management District (Lassen Co.), Long Valley Groundwater Management District (Lassen Co. and Sierra Co.), Sierra Valley Groundwater Management District (Sierra Co.), Mendocino City Community Services District (Mendocino Co.), Mono County Tri-Valley Groundwater Management District, Pajaro Valley Groundwater Management Agency (Santa Cruz), Ojai Groundwater Management Agency (Ventura Co.), Fox Canyon Groundwater Management Agency (Ventura Co.), and the Monterey Peninsula Water Management District (Monterey Co.). See California Department of Water Resources, Water Facts: Groundwater Management Districts or Agencies in California (1996).

[39] Such as the Orange County Water District, Santa Clara Valley Water District, and the Monterey County Water Resources Agency.

[40] See In re Mass, 219 Cal. 422, 424-25 (1933); Ex parte Elam, 6 Cal. App. 233, 237 (1907).

[41] Baldwin v. County of Tehama, 31 Cal. App. 4th 166, 173-74 (1994, 3rd Dist.); review denied, Cal. Sup.Ct., March 17, 1995. Baldwin held that state law, namely AB 3030, specially enacted local districts and California Water Code Section 1220 (about which more, later) do not preempt city and county management of groundwater resources. State law preempts local ordinances only when "the subject matter has been so fully and completely covered by general law as to clearly indicate that it has become exclusively a matter of state concern . . ." or "the subject matter has been partially covered by general law couched in such terms as to indicate clearly that a paramount state concern will not tolerate further or additional local action. . . ." .

[42] The following counties have passed groundwater management ordinances that govern the extraction and exportation of groundwater (dates of the most recent amendment are noted): Butte Co. 1996; Colusa Co. 1998; Fresno Co. 2000; Glenn Co. 2000; Imperial Co. 1998; Inyo Co. 1998; Kern Co. 1998; Lake Co. 1999; Madera Co. 2001; Modoc. Co. 2001; Napa Co. 1999; Sacramento Co. 1952 Water Act (Sec 32 on GW mgmt added 1985); San Benito Co., 1995; San Diego Co. 1991; San Joaquin Co. 1996; Shasta Co. 1998; Siskiyou Co. 2001; Tehama Co. 1994; Yolo Co. 1996. Ordinances have been proposed or are pending approval in a number of other counties.

[43] Groundwater is generally defined as "all water below the surface not in known and definite channels." Since none of the ordinances exempt imported water from this definition, the ordinances arguably apply to banked, imported water.

[44] For example, see Colusa County Code §§ 43-3, 43-4 and Shasta County Ordinance No. SCC 98-1, §§ 18.08.030, 18.08.040.

[45] The Board must make an injury determination when approving the change order to transfer water into the aquifer and likely retains jurisdiction over the subsequent rediversion of the stored water. Parties potentially affected by the banking

operation would have the opportunity to protest the project as well as seek protection from the Board if the project operation affects their rights. On the other hand, the Board's authority to protect the banker is not symmetrical; the Board does not have the power to prevent groundwater pumpers from taking the banked water. Legal counsel to the State Board suggests that the instances of actual conflict may not be frequent in that, in situations where there is a competent county regulatory regime, the Board would likely defer to the county and exercise its authority only when necessary.

[46] The County of Origin and Watershed of Origin statutes by definition only apply to water that originates in the county or watershed of origin.

[47] California Water Code § 1220: "(a) No groundwater shall be pumped for export from within the combined Sacramento and Delta-Central Sierra Basins . . . unless the pumping is in compliance with a groundwater management plan that is adopted by ordinance pursuant to subdivision (b) by the county board of supervisors, in full consultation with affected water districts, and that is subsequently approved by a vote in the counties or portions of counties that overlie the groundwater basin, except that water that has seeped into the underground from any reservoir, afterbay, or other facility of an export project may be returned to the water supply of the export project. . . ."

[48] Injury to groundwater appropriators is unlikely, however, as their rights are subordinate to the overlying parties who are participating in the *in lieu* banking project.

[49] California Water Code § 1005.2 and 1005.4 states that where a nontributary source of water (imported foreign water or conserved water otherwise unavailable to the aquifer) is used *in lieu* of groundwater pumping, a reduction or cessation of groundwater pumping to permit groundwater replenishment is deemed a beneficial use of water and will not result in loss, reduction or forfeiture of the groundwater rights.

CASE STUDIES

[50] More recent geologic investigations by the Department of Water Resources Northern District Office suggest that the western boundary of the basin may not coincide with the Sacramento River. The southern boundary is likewise in question due to limited hydrogeologic characterization of the stratigraphy surrounding the Sutter Buttes. A further complication related to the southern boundary is that the greater reliance on groundwater south of the Sutter Buttes has created a net outflow of regional groundwater from the Butte Basin.

[51] Camp, Dresser & McKee, Inc. 2001. Butte County Water Inventory and Analysis Report 5-8 (Draft).

[52] Department of Water Resources, State of California (DWR), 1978. Evaluation of Ground Water Resources: Sacramento Valley, Bulletin 118-6, at 136.

[53] L.S. Dixson, N.Y. Moore, and S.W. Schechter, California's 1991 Drought Water Bank, Economic Impacts in the Selling Region, RAND, Santa Monica, CA (1993).

[54] Camp, Dresser & McKee, Inc., Butte County Water Inventory and Analysis Report 4-8 (Draft) (2001).

[55] M. Planert and J.S. Williams, Groundwater Atlas of the United States, Segment 1: California and Nevada, U.S. Geological Survey, Hydrologic Atlas HA-730B (1995).

[56] Department of Water Resources, State of California (DWR), Program Environmental Impact Report: State Drought Water Bank, Sacramento, CA.(1993).

[57] Department of Water Resources, State of California (DWR), State Water Project supplemental water purchase program: Draft program environmental impact report (1996).

[58] American River Basin Cooperating Agencies and Sacramento North Area Groundwater Management Authority (ARBCA/SNAGMA), The Opportunity for Large-Scale Groundwater Banking and Exchange in Northern Sacramento and Southern Placer Counties, 1 (January 2000).

[59] *Ibid*.

[60] *Ibid*.

[61] Personal communications with Mr. Marshall Davert, Project Manager, Montgomery-Watson, 2000.

[62] DWR, *supra* note 52, at 8-6.

[63] ARBCA/SNAGMA, *supra* note 58.

[64] Personal communications with Mr. Jim McCormack, Sacramento, Office of Metropolitan Water Planning, September 18, 2000.

[65] ARBCA/SNAGMA, *supra* note 58, at 8-9.

[66] Water Forum Groundwater Management Element 2-5 (1998).

[67] *Ibid*.

[68] Water Forum Groundwater Management Element, *supra* note 66, at 8.

[69] Joint Powers Agreement Between the City of Citrus Heights, the City of Folsom, the City of Sacramento, and the County of Sacramento Creating the Sacramento North Area Groundwater Management Authority, August 11, 1998.

[70] *Ibid*., p. 6.

[71] *Ibid.*

[72] Personal communications with Mr. Jim McCormack.

[73] *Ibid*.

[74] American River Basin Cooperating Agencies, Regional Water Master Plan, Phase I Final Report, Technical Memoranda, TM 2: Regional Water Master Plan Goals and Objectives 2-3 (June 1999).

[75] ARBCA, Regional Issues Committee Report — Overview of Regional Organizations, n.d.

[76] ARBCA/SNAGMA/USBR , Sacramento North Area Conjunctive Use Program: A Partnership for Regional Water Planning (June 1999).

[77] ARBCA/SNAGMA, *supra* note 58, at 4.

[78] ARBCA, *supra* note 75.

[79] *Ibid*.

[80] ARBCA/SNAGMA, *supra* note 58, at 5-6.

[81] *Ibid*.

[82] Personal Communications with Mr. Jim McCormack.

[83] Personal communications with Mr. Marshall Davert, September 2000.

[84] Information provided by Mr. Bill Edgar, McDonough Holland & Allen, February 25, 2000.

[85] Montgomery Watson, American River Basin Cooperating Agencies, Regional Water Master Plan, Phase I Final Report, Technical Memoranda, TM 1 Regional Water Master Plan Phase I Project Management Plan 1-9 (1999).

[86] Montgomery Watson, American River Basin Cooperating Agencies, Regional Water Master Plan, Phase II , Technical Memoranda, TM 1: Project Management Plan, 1-16 - 1-27.

[87] ARBCA, *supra* note 75.

[88] Brown and Caldwell, Eastern San Joaquin County Groundwater Study Summary Report 2 (October 1985).

[89] California Department of Conservation, Farmland Conversion Report 1994 to 1996, Publication No. FM 98–01, 20–21.

[90] Brown and Caldwell, *supra* note 88.

[91] *Ibid*, p. 4.

[92] US Army Corps of Engineers, Sacramento District, Farmington Dam and Reservoir, California WRDA 1996 Section 411— Conjunctive Use Study 11-10 (December 1998).

[93] Baseline Environmental Consulting, Final Environmental Impact Report, San Joaquin County Comprehensive Planning Program, ER 91-3 (May 1992).

[94] US Army Corps of Engineers, *supra* note 92, p. II-9.

[95] Brown and Caldwell, *supra* note 88, at 1.

[96] DWR, The California Water Plan Update, Bulletin 160-98, November 1998, at 8–29.

[97] Stockton East Water District, US Army Corps of Engineers, loc. cit.

[98] US Army Corps of Engineers, *supra* note 92, p. I-1.

[99] Stockton East Water District, History, www.sewd.net/history.html.

[100] *Ibid*.

[101] Stockton East Water District, US Army Corps of Engineers, Solving the Water Shortage in Eastern San Joaquin County, Informational Brochure, 2000, at 1.

[102] ESJPWA, Groundwater Recharge & Banking in Eastern San Joaquin County, 5.

[103] East Bay Municipal Utility District, Increasing Water Supply Reliability, Technical Publication, 4 (1996).

[104] *Ibid*.

[105] DWR, *supra* note 96.

[106] East Bay Municipal Utility District, Increasing Water Supply Reliability, Technical Publication, 3-4 (1996).

[107] DWR, *supra* note 96.

[108] Brown and Caldwell, *supra* note 88, at 13.

[109] San Joaquin County Flood Control and Conservation District Groundwater Monitoring Program Evaluation, 1999.

[110] Personal communications with Ms. Jeanne Zolezzi, SEWD Counsel, May 17, 2000.

[111] Personal communications with Mr. Fran Forkas, City of Lodi, August 21, 2000.

[112] Mark S. Williamson, East Bay Municipal Utility District Conjunctive Use Planning in San Joaquin County, Proceedings of the Twentieth Biennial Conference on Ground Water, Water Resources Center Report No. 88, University of California, Davis, 72 (September 11-12, 1995).

[113] Personal Communication with Mr. John Pulver, San Joaquin County Water Resources Coordinator, June 5, 2000.

[114] East San Joaquin Parties Joint Exercise of Powers Agreement, East San Joaquin Parties Water Authority, Article I, Section 1.02.

[115] Williamson, *supra* note 112, at 72.

[116] *Ibid*, at 75.

[117] Williamson, *supra* note 112, at 75.

[118] Amended Memorandum of Agreement Between the East Bay Municipal Utility District and the East San Joaquin Parties Water Authority, November 5, 1997.

[119] Boyle Engineering Corp., Beckman Test Project, 1–10 (1999).

[120] Dogen Hannah*, Water Banking Reviewed,*The Record (Stockton) February 13, 2000.

[121] *Ibid*.

[122] Personal Communications with Mr. Richard Prima, City of Lodi, July 2000.

[123] Personal Communications with Mr. John Pulver, March 2001.

[124] Ordinance Amending Division 8 to Title 5 of the Ordinance Code of San Joaquin County Regarding the Extraction and Exportation of Groundwater from San Joaquin County, Chapter 3, Section 5-8335 - Section 5-8340.

[125] From a presentation to the Advisory Water Commission of SJC Flood Control and Water Conservation District by Anthony Saracino, ESJPWA Executive Director, August 9, 2000.

[126] Per Anthony Saracino, ESJPWA Executive Director, August 2000.

[127] Williamson, *supra* note 112, at 72.

[128] *What People are Saying,* San Joaquin Farm Bureau News, August, 2000.

[129] Jim Nickles, *A Special Report, Divided over Water*, The Record, May 4, 1998, at A4.

[130] Mike Treleven, *Stockton East Studies Overdraft Solutions*, San Joaquin Farm Bureau News, February 2000.

[131] Personal communications with Mr. Richard Prima, Director of Public Works, City of Lodi, July 2000.

[132] Personal communications with Ms. Jeanne Zolezzi, SEWD Counsel, May 2000.

[133] Ordinance Amending Division 8 to Title 5 of the Ordinance Code of San Joaquin County Regarding the Extraction and Exportation of Groundwater from San Joaquin County, Chapter 3, Section 5-8345.

[134] Amended Memorandum of Agreement Between the East Bay Municipal Utility District and the East San Joaquin Parties Water Authority, November 5, 1997.

[135] Per Mr. Anthony Saracino, ESJPWA Executive Director, August 2000.

[136] Amended Memorandum of Agreement Between the East Bay Municipal Utility District and the East San Joaquin Parties Water Authority, Article 7 Indemnification, 7–8.

[137] Madera Irrigation District AB3030 Groundwater Management Plan, Boyle Engineering Corporation, 23 (May 1999).

[138] *Farmers Worry Growth Squeeze Will Be Harmful,* Fresno Bee, November 8, 1998, TELEGRAPH section, at A18.

[139] Madera Irrigation District, *supra* note 137, at 1.

[140] Fresno Bee, *supra* note 138.

[141] Madera Irrigation District, *supra* note 137, at 10.

[142] USBR, "Toolbox" Reserve Water Document, n.d.

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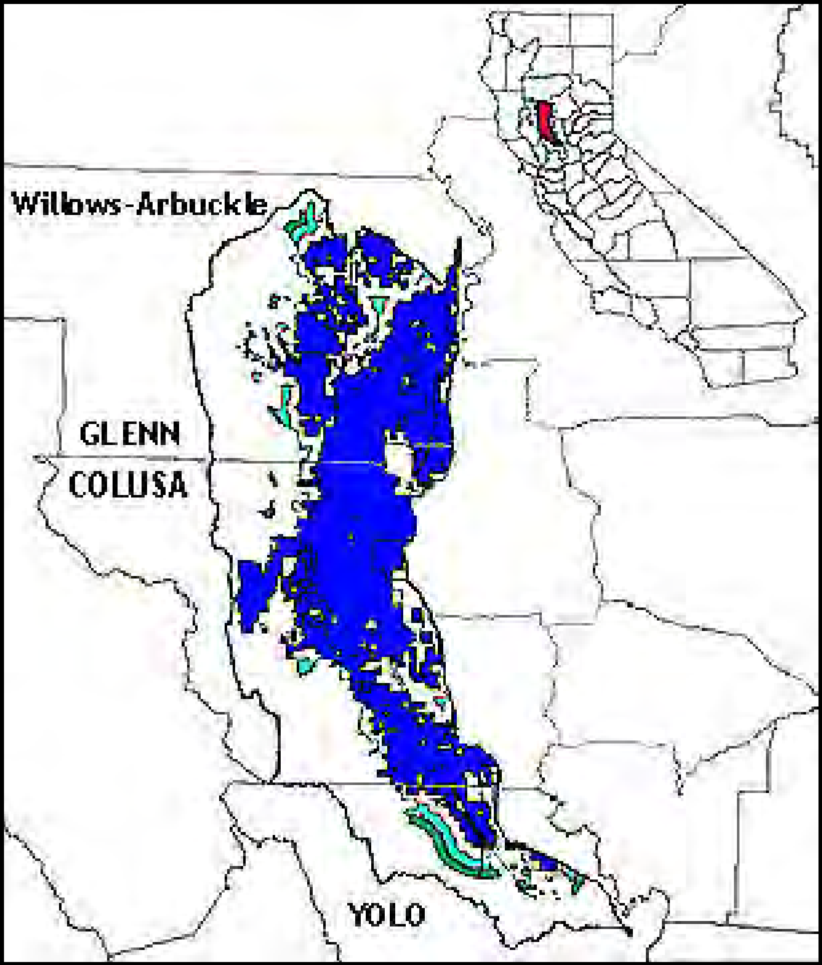
SYSTEM-WIDE CONJUNCTIVE WATER MANAGEMENT

ESTIMATING THE POTENTIAL FOR IN LIEU CONJUNCTIVE WATER MANAGEMENT IN THE CENTRAL VALLEY OF CALIFORNIA



THE NATURAL HERITAGE INSTITUTE

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This report and others from this project are available on-line from NHI's website at www.n-h-i.org or contact the Natural Heritage Institute at the address below.

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The Natural Heritage Institute is a non-profit natural resource conservation organization composed of technical and legal specialists and dedicated to the improvement of the laws and institutions that manage our natural heritage both domestically and internationally.

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1.0 Introduction

Over the course of the past several years conjunctive use has emerged as a key element of California water management strategy. This fact is most prominently embodied in the call for 500,000 to 1,000,000 acre-feet of additional groundwater storage made in the CALFED Record of Decision (RoD). In response to this call efforts are underway across the state to design and develop conjunctive use programs—efforts that are being supported financially by CALFED and by a number of other State and Federal agencies. In keeping with the current agency philosophy that groundwater management initiatives should grow out of local initiatives, the vast majority of these efforts focus on projects with a well-defined local geographic scope.

While these projects, when viewed as a whole, will surely produce important water management flexibility in the future, they represent a change in focus from historical surface water development efforts in California that often adopted a more statewide geographic perspective. The impact of this history is now manifest in the far-flung distribution of reservoirs, canals and water users that characterize the California water system. While this system has dramatically altered the natural hydrology of the Sacramento and San Joaquin Basins, it also offers remarkable opportunities for management integration and innovation, including the possibility of regional and system-wide conjunctive water management initiatives that may offer benefits that would be missed by adopting a purely local conjunctive use planning perspective.

In recent years, the Natural Heritage Institute (NHI) has been exploring the role that system-wide conjunctive use and groundwater banking focused on the reservoirs and aquifers in the Central Valley can play in balancing the water needs of California's agricultural, urban and environmental interests. The starting point of each element of this analysis is that the interests of groundwater users overlying individual groundwater basins in the Central Valley must be protected, or even enhanced, when evaluating any system-wide conjunctive use initiative. If system-wide integration of a groundwater basin causes harm to the historic users of the resource, no amount of cajoling can compel the basin's managers to pursue this option. The rules governing the use of groundwater in California simply do not accommodate this possibility. However, determining whether system-wide integration of a groundwater basin can generate a broad spectrum of benefits that accrue both locally and across the state requires analysis. The System-Wide Conjunctive Management Series published by NHI, which has been supported by the U.S. Bureau of Reclamation and a consortium of other public water management agencies, attempts to respond to this need.

Previous reports that have been published in the Series include:

- *A Feasibility Study of Maximal Scale Program of Groundwater Banking in California* (NHI 1999), which dealt with the technical feasibility increasing the yield of the California water system through the re-operation of the State's major surface water reservoirs as part of a system-wide groundwater banking program, and included three case studies.

- *Designing Successful Groundwater Banking Programs in the Central Valley* (NHI 2001a), which described in detail the legal and institutional opportunities and constraints suggested by the successes and failures encountered during earlier attempts to implement ambitious groundwater management projects.
- *The Hydrogeologic Suitability of Potential Groundwater Banking Sites in the Central Valley of California* (NHI 2001b), which proposed an index to rank the hydrogeologic suitability of various groundwater basins in the Central Valley as targets for direct recharge groundwater banking based on geologic, groundwater quality, soils and hydrologic considerations.

Others will follow, subject to the availability of financial resources, on:

- Design specifications for local groundwater management institutions;
- The potential for integrating conjunctive use into reservoir re-operation strategies that are also intended to enhance downstream fluvial processes;
- The analysis of institutional, land use, infrastructure, and environmental and other factors bearing upon siting decisions for groundwater banks;
- The results of “gaming” analysis of a series of conjunctive use configurations in the Central Valley;
- Economic optimization analysis; and
- The final feasibility of and strategic plan for an appropriate system-wide conjunctive water management initiative.

The current report contains analysis on the potential role that *in lieu* conjunctive water management in the Central Valley could play in a system-wide conjunctive water management initiative. This conjunctive use strategy relies upon offsetting historical groundwater pumping with surface water deliveries from project participants during times of excess surface water supply. These extended deliveries of surface water could also be part of a reservoir re-operation strategy designed to enhance the overall yield of the major water supply reservoirs in the Central Valley (NHI 1999). Any foregone groundwater pumping that results from the delivery of surplus surface water or reservoir re-operation is, in turn, considered to be stored groundwater water that can be reclaimed by project participants during times of surface water shortfalls. This strategy, which obviously rests heavily on institutional and accounting arrangements, is an alternative to direct aquifer recharge of surface water either during years of surplus or as part of the reservoir re-operation that was the focus of previous analyses published in the System-Wide Conjunctive Management Series (NHI 2001b).

In theory, any historic user of groundwater, either municipal or agricultural, could receive surface water deliveries *in lieu* of groundwater pumping. An interesting example of urban *in lieu* conjunctive use is emerging in the Sacramento Region north of the American River, where several municipal water districts have formed a joint powers authority to coordinate the use of their individual American River surface water rights and pumping from their common underlying aquifer (Winkler 2002). In addition, the delivery of surface water to offset groundwater pumping does not necessarily require water delivery outside of the jurisdiction of the original surface water rights holder.

In many, perhaps most, water districts irrigators draw upon both surface water and groundwater to meet crop water requirements based on water availability, delivery timing and overall cost considerations. In this setting, however, realizing viable *in lieu* conjunctive water management opportunities is likely to occur as part of standard internal water district planning.

Outside of urban regions and water districts endowed with surface water supplies, there remains a substantial opportunity to carry out *in lieu* conjunctive use by delivering available surface water to irrigated lands lying outside of the boundaries of established surface water delivery districts. These are lands that rely completely on groundwater pumping as a source of irrigation water. While water districts are both common and extensive in the Central Valley, there remain vast tracts of land that fall into the land use category of "unincorporated irrigated agriculture". Evaluating the extent of delivering surface water to these lands as part of an *in lieu* conjunctive use program, either during years of surplus or as part of an overall reservoir re-operation strategy, is the focus of this report.

The report continues in Section 2.0 with a brief discussion of the evaluation criteria that can be used to evaluate where in the Central Valley an *in lieu* conjunctive water management program could be implemented. Subsequently, in Section 3.0, the analytical methodology used to examine these evaluation criteria is presented, including a discussion of the data collected and tools used. Section 4.0 presents the results of analysis of the evaluation criteria and an estimate of the scale of potential *in lieu* conjunctive water management in the Central Valley. The report closes with some thoughts on the implications of this work on the System-Wide Conjunctive Water Management Initiative.

2.0 Evaluation Criteria for Assessing *In Lieu* Conjunctive Use Opportunities

As mentioned in Section 1.0, this report explores the potential for implementing *in lieu* conjunctive water management projects on agricultural land in the Central Valley that has historically relied solely on groundwater pumping to supply irrigation water. One consideration in developing such a program is the availability of surface water for delivery to these lands. The possibility of generating new surface water was discussed in an earlier publication in the System-Wide Conjunctive Water Management Series (NHI 1999). Other hydrologic modeling exercises have also focused on enhancing the storage capacity available to manage surface water in the Central Valley. What has been missing, at least in the context of *in lieu* conjunctive water management, is an inventory of the magnitude of the opportunity for historic agricultural users of groundwater to accept any available surface water supplies.

While the willingness of historic groundwater users to participate in such a program will turn primarily on local considerations related to cost and assurances, there are some physical characteristics that can make a particular region attractive for *in lieu* conjunctive use. In pursuing this investigation, three evaluation criteria that will influence the viability of this water management strategy were identified.

- The relative contribution of surface water and groundwater to irrigated agriculture in an area of interest. Ideally *in lieu* groundwater banking will occur in areas where significant amounts of groundwater pumping for irrigation takes place in the same locale where significant amounts surface water are available to offset groundwater pumping.
- The physical proximity of lands irrigated solely with groundwater to water districts that own the surface water distribution network that would be extended to deliver surface water in lieu of groundwater pumping.
- The amount of available aquifer storage space to accommodate the "stored" groundwater that will be left behind by delivering surface water to land historically dependent on groundwater pumping.

The analytical methodology used to evaluate each of these parameters is found in the following section.

3.0 Analytical Methodology

Having selected three criteria for evaluating the potential for *in lieu* groundwater banking in the Central Valley, we developed an analytical methodology that would allow for comparisons among different parts of the region. These are discussed below.

3.1 Relative Contribution of Surface Water and Groundwater

This evaluation criterion relates to local balance between the use of surface water and groundwater to meet crop water requirements on irrigated lands. If all of the land in a particular area has access to adequate surface water, then there is little possibility to increase groundwater storage by offsetting groundwater pumping. Conversely, in an area characterized uniquely by groundwater pumping there is no surface water to more widely distribute, either in times of excess supply or as part of reservoir re-operation. This suggests that *in lieu* conjunctive water management is a strategy best suited for areas where both groundwater and surface water contribute to the overall agricultural water supply.

The question becomes, however, how to define the boundaries of an area for analysis. An area such as the Central Valley certainly relies upon a mix of surface water and groundwater to meet crop water requirements. According to the most recent State Water Plan Update (DWR 1998), 28.3 MAF of surface water and 9.2 MAF of groundwater are used during average water years in the Central Valley. At this scale it is possible to imagine that surface water supplies might be available to offset groundwater pumping as part of *in lieu* conjunctive water management. This conclusion, however, does little to help in identifying where the most promising opportunities for this arrangement lie. To achieve this objective some more refined characterization of the mix of available surface water and groundwater for irrigation is required.

The State Water Plan Update (Bulletin 160), published once every five years by the Department of Water Resources (DWR), was identified as the logical source of information for developing this more refined characterization. Bulletin 160 reports on the composition of water supplies and demands at the level of 10 Hydrologic Regions in the State (Figure 3.1) and uses this data to anticipate the evolution of the statewide balance of water supply and demand over a planning horizon of several decades.

Figure 3.1: Hydrologic Regions Defined by California Department of Water Resources for the Purpose of Statewide Water Planning (DWR 1998)

In actuality, however, the data published in Bulletin 160 are aggregated up from water balance calculations performed at the level of 280 Detailed Analysis Units (DAU) defined by DWR (Figure 3.2). These range in area from roughly 11 mi^2 up to over 3600 mi^2. While the actual logic used to delineate these DAUs is not included in Bulletin 160, they appear to be based largely on the location of local important physical (mountains, rivers, distribution canals) and political (local government and water district boundaries) features.

Figure 3.2: Detailed Analysis Units Defined by California Department of Water Resources for the Purpose of Conducting Water Balance Calculations

Given their foundational role as the level at which water supply and demand data are actually assembled and analyzed, the DAUs were deemed the most appropriate unit for evaluating the local mix of surface water and groundwater used by irrigated agriculture. As the scope of the current investigation was limited to *in lieu* conjunctive water management opportunities in the Central Valley, a set of 56 DAUs was identified for further analysis (Figure 3.3). The logic used for selecting these DAUs was that the most significant portion of the DAU lies within the relatively flat, heavily agricultural region lying between the Coast Range Mountains and the Sierra Nevada Foothills. This logic also appears to have driven the original definitions of the DAUs, as those selected generally lie entirely within this zone. Details regarding the identifying code number, name, Hydrologic Region and surface area of the 56 selected DAUs are presented by identifying code number in Table 3.1.

Figure 3.3: Detailed Analysis Units in the Central Valley Selected for Analysis of the Potential for *In Lieu* Conjunctive Water Management

DWR's regional offices maintain databases for the various DAUs around the state. 1995 and 1996 data for the Central Valley DAUs shown in Figure 3.3, which presumably were used to develop the 1998 edition of Bulletin 160, were obtained directly from DWR personnel in the Redding, Sacramento and Fresno offices. A number of different data sets were extracted from these Excel spreadsheets, some of which were used to perform calculations designed to evaluate the relative contribution of surface water and groundwater to the irrigation water supply in the DAU.

Table 3.1: Relevant Details Pertaining to the 56 Central Valley DAUs Selected for Analysis of the Potential for *In Lieu* Conjunctive Water Management

ID No.	Name	Hydrologic Region	Area (mi^2)	ID No.	Name	Hydrologic Region	Area (mi^2)
141	Redding West	Sacramento River	416.1	211	Merced Stream Group	San Joaquin River	241.0
142	Red Bluff-Orland	Sacramento River	868.5	212	El Nido-Stevinson	San Joaquin River	339.6
143	Redding East	Sacramento River	240.9	213	Madera-Chowchilla	San Joaquin River	283.1
144	Los Molinos	Sacramento River	317.3	214	Adobe - Valley Eastside	San Joaquin River	286.2
162	Lower Cache Creek	Sacramento River	550.0	215	Gravelly Ford	San Joaquin River	248.2
163	Willows-Arbuckle	Sacramento River	1426.1	216	West Side	San Joaquin River	1104.0
164	Glenn-Knights Landing	Sacramento River	239.8	233	Fresno	Tulare Lake	411.2
165	Meridian-Robbins	Sacramento River	159.4	234	Academy	Tulare Lake	73.1
166	Durham-Sutter	Sacramento River	418.0	235	Raisin	Tulare Lake	291.1
167	Butte City	Sacramento River	148.1	236	Consolidated	Tulare Lake	274.2
168	Yuba City-Gridley	Sacramento River	400.9	237	Lower Kings River	Tulare Lake	277.8
170	Honcut Valley	Sacramento River	66.0	238	Hanford-Lemoore	Tulare Lake	266.3
171	Yuba	Sacramento River	259.0	239	Alta	Tulare Lake	208.8
172	Placer	Sacramento River	592.8	240	Orange Cove	Tulare Lake	84.0
173	Sacramento	Sacramento River	221.8	241	Tulare Lake	Tulare Lake	403.1
180	Elk Grove	San Joaquin River	311.4	242	Kaweah Delta	Tulare Lake	695.9
181	Ione-Jenny Lind	San Joaquin River	303.0	243	Tule Delta	Tulare Lake	660.3
182	Lodi	San Joaquin River	618.8	244	Westlands	Tulare Lake	1016.9
184	Bachelor Valley	San Joaquin River	109.1	245	Kettleman Plain	Tulare Lake	264.0
185	San Joaquin Delta	San Joaquin River	625.3	246	South Tulare Lake	Tulare Lake	146.8
186	Sacramento Delta	Sacramento River	437.7	254	Kern Delta	Tulare Lake	531.3
191	Vacaville	Sacramento River	406.6	255	Semitropic	Tulare Lake	426.1
205	South San Joaquin ID	San Joaquin River	153.5	256	North Kern	Tulare Lake	365.3
206	Modesto-Oakdale	San Joaquin River	286.9	257	Northeastern Kern	Tulare Lake	341.5
207	Modesto Reservoir	San Joaquin River	171.5	258	Arvin-Edison	Tulare Lake	333.7
208	Turlock	San Joaquin River	319.2	259	Antelope Plain	Tulare Lake	644.1
209	Turlock Lake	San Joaquin River	224.4	260	Buena Vista Valley	Tulare Lake	187.5
210	Merced	San Joaquin River	244.0	261	Wheeler Ridge-Maricopa	Tulare Lake	271.3

The extracted data sets included:

- Reported applied water to agriculture (AGAW)
- Reported evaporation of applied water (ETAW)
- Reported applied surface water to agriculture (ASW)
- Reported applied groundwater to agriculture (AGW)

These values are considered to be reported because it was generally not clear from the spreadsheets how the numbers were developed and in several cases it was evident that the numbers were calculated from other variables (see the text box on the following page). As they represented the best available data, however, these values were used to calculate the following variables:

- Irrigation Efficiency (E) = ETAW/AGAW
- Agricultural Surface Water Contribution (%SW) = ASW/AGAW
- Agricultural Groundwater Contribution (%GW) = 1 - %SW

The values of ETAW, ASW, AGW, %SW and %GW were then tabulated and graphed in order to identify DAUs with the proper mix of surface water and groundwater use to make them attractive candidates for *in lieu* conjunctive water management. The results of this analysis are presented in Section 4.0. The estimated irrigation efficiency was used to examine where improvements in irrigation water management might allow for a wider distribution of available surface water. This opportunity is also discussed in greater detail in the Results section below.

3.2 Physical Proximity of Lands Irrigated Solely with Groundwater

In addition to having an appropriate mix of surface water and groundwater use for irrigation, in order to implement an *in lieu* conjunctive use program it is desirable if much of the land irrigated solely with groundwater lies in close proximity to water districts. These are the entities endowed with the surface water delivery networks that would presumably be expanded to deliver surface water to these lands *in lieu* of groundwater pumping. This criterion was evaluated by carrying out spatial analysis on databases describing the location of water districts and the distribution of agricultural lands within the 56 Central Valley DAUs.

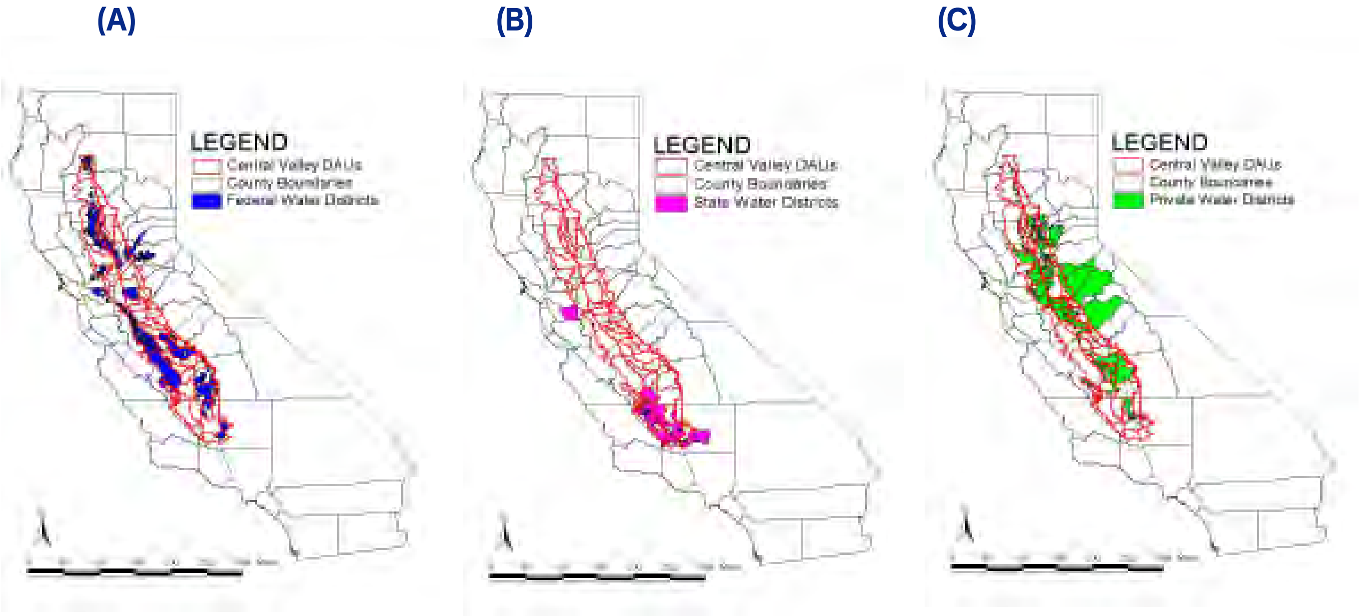
The U.S. Bureau of Reclamation's (USBR) Mid-Pacific Region originally developed the water district databases used in this exercise. The database differentiated water districts into three categories: Federal districts that contract with the USBR for water, State districts that contract with the State Water Project for water, and private districts that own and operate their own surface water supply systems. Districts lying at least partially within the Central Valley DAUs that are the basis of the current analysis are shown in Figure 3.4.

Observations on the DAU Databases

Given their foundational role in developing the aggregate Hydrologic Region water supply and demand numbers reported in Bulletin 160, it was surprising to discover that the DAU databases are neither easy to acquire nor uniform in format. The following observations regarding the DAU databases are offered in the hope that they may assist in expanding the utility and integrity of this important dataset.

1. DAU databases for the entire State should be available from a single source, preferably on-line.
2. DAU databases should follow a single transparent format so that interested parties outside of DWR can easily use them.
3. Detailed meta-data descriptions of the numbers included in the DAU databases should be developed. This meta-data should draw a clear distinction between what has been measured and what has been estimated. For estimated data, the methodology used to arrive at the estimate should be included.
4. For DAUs in the San Joaquin River and Tulare Lake Hydrologic Regions, a groundwater use is estimated to be a closure term in a mass balance that relies upon several coarse assumptions. Given the importance of groundwater in California, a better method of estimating groundwater use must be developed.
5. Bulletin 160 should include an appendix that clearly lays out how the uncertainty in the DAU water budget calculations can aggregate up into the reported Hydrologic Region supply and demand numbers.

Figure 3.4: Location of Federal (A), State (B) and Private (C) Water Districts Located at Least Partially within the 56 Selected Central Valley DAUs

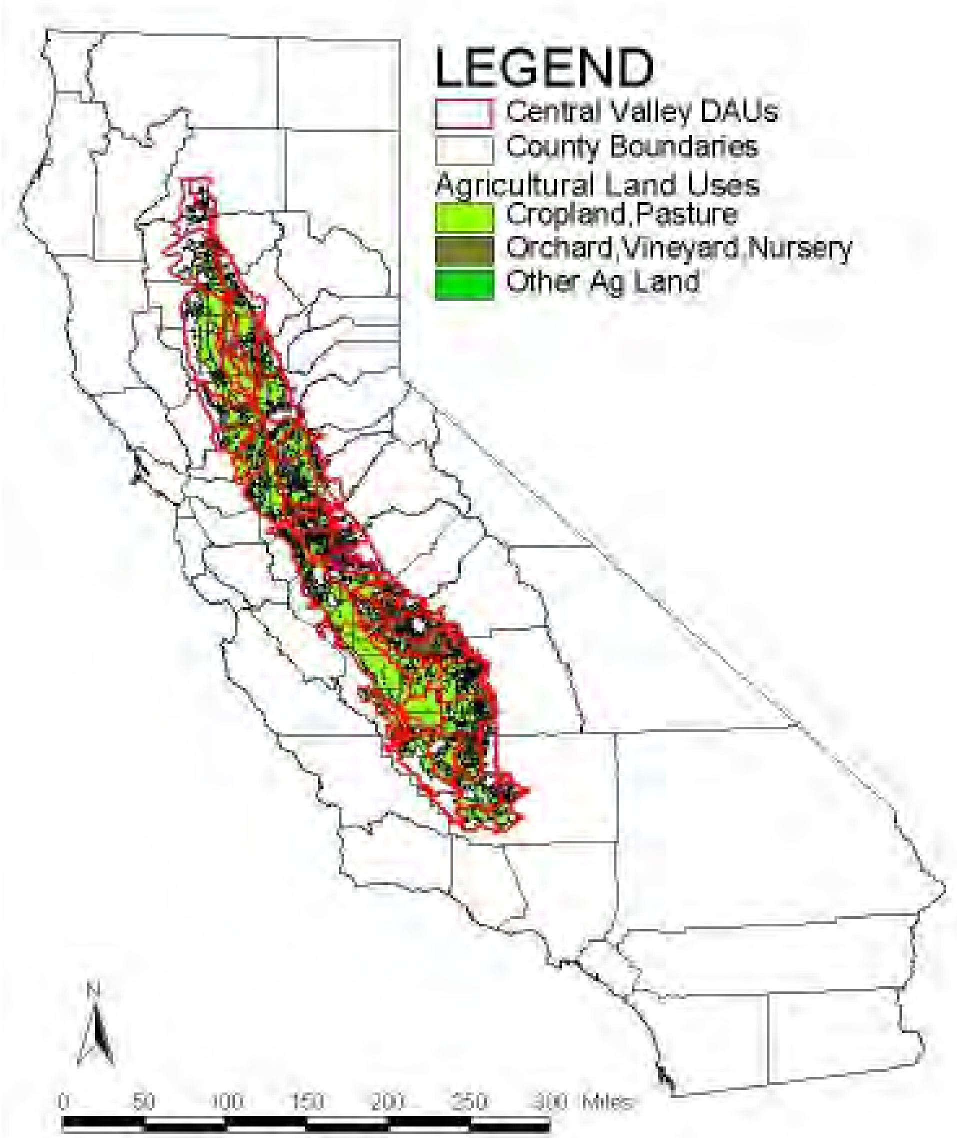


In order to estimate the amount of irrigated land historically irrigated solely with surface water that lies in close proximity to these districts, a land use/land cover database developed by the U.S. Geological Survey (USGS) at a scale of 1:250,000 was obtained. This database was edited so that it contained only land that would be under irrigation by removing all urban, industrial, non-irrigated agriculture and natural land use areas. The resulting database is found in Figure 3.5.

ArcView 3.2 buffers of 1, 2 and 3 miles were drawn around the portion of the Federal, State and private districts found within each of the 56 Central Valley DAUs. This buffering was performed separately for each of the three categories of water districts. Any land within the buffers of a particular water district category but inside the boundaries of another category of water district was eliminated from consideration. The remaining buffers were subsequently clipped to find those areas that contained irrigated agricultural land use types where groundwater pumping would presumably occur. The area of the remaining land was then calculated to evaluate the physical proximity of lands irrigated solely with groundwater to established water districts.

By treating the different categories of water districts separately, some of the irrigated lands located outside of the boundaries of incorporated water districts could be included in more than one set of buffers. As such the total amount of land irrigated by groundwater in a DAU within a given distance of any water district cannot be calculated by summing the area of buffers around the different categories of water districts. The analysis was carried out in this manner because the Federal, State and private districts are managed by different entities that generally make their own planning decisions.

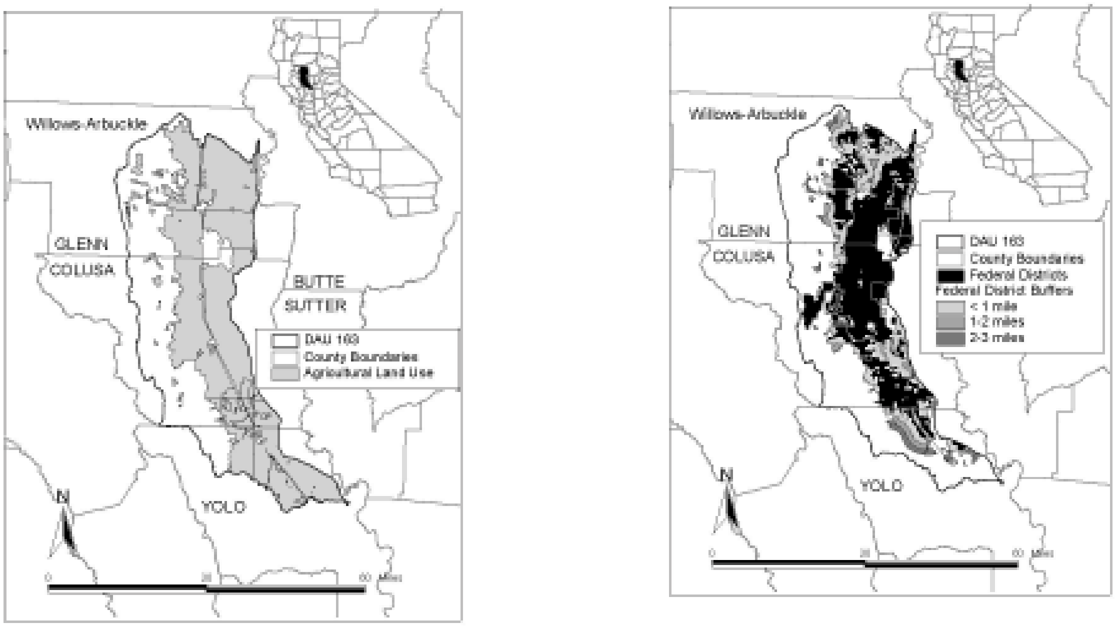
Figure 3.5: Irrigated Agricultural Land Use Type Located within the 56 Selected Central Valley DAUs



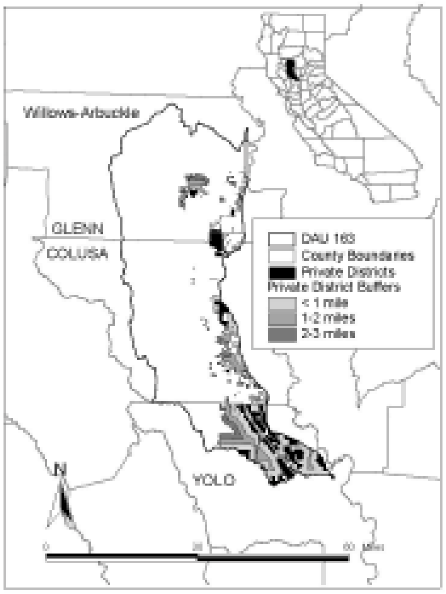
The basic framework for the spatial analysis used to evaluate this criterion is shown in Figure 3.6 for DAU 163, Willows-Arbuckle, which includes Federal and private water districts as well as substantial areas of irrigated land lying outside of district boundaries.

Figure 3.6: Spatial Analysis Framework for DAU 163, Willows-Arbuckle, with Area of Irrigated Agriculture (A), Federal Districts with 1-, 2- and 3-Mile Buffers (B), Private Districts with 1-, 2- and 3-Mile Buffers (C), and Tabulated Results (D)

(A) (B)



(C) (D)



Buffer Distance (miles)	Area Relative to Federal Districts (miles)	Area Relative to Private Districts (miles)
< 1	180.3	92.1
1-2	30.1	40.8
2-3	21.3	21.1

Maps similar to those shown in Figure 3.6 are shown for all of the Central Valley DAUs in Appendix A. The results of the spatial analysis of this criterion are discussed in Section 4.0.

3.3 Amount of Available Aquifer Storage Space

When groundwater pumping is foregone as a result of *in lieu* surface water deliveries, the result is that more water is left in aquifer storage than otherwise would have been present. Given ample substitution of surface water, the increase in aquifer storage will translate to higher water levels in the unused wells. If the well is tapping an unconfined aquifer where the water table already lies close to the ground surface, then the additional groundwater storage may be problematic. High water tables can create drainage problems for agricultural crops and cause damage to structures with deep foundations. In addition, high water tables can result in increased seepage to streams and rivers meaning that some portion of the water stored in the aquifer as a result of *in lieu* surface water deliveries may be lost. Wells tapping deeper, confined aquifers are less prone to the problems associated with high water tables although increases in the piezometric surface in these wells may reduce seepage from overlying unconfined aquifers, leading indirectly to a rising water table.

Both types of aquifers are tapped by agricultural wells in the Central Valley. In the San Joaquin and Tulare Lake Basins in particular, much of the groundwater used for irrigation is pumped from the confined aquifer below the Corcoran Clay. In either case, *in lieu* conjunctive use becomes less attractive if either the water table or the piezometric surface is already close to the ground surface prior to the delivery of surface water to historic groundwater users. Identifying regions with ample available aquifer storage space was carried out using data available in the Fall 1999 DWR water level survey of wells in the Central Valley (the latest complete data set available on-line). Figure 3.7 depicts the wells included in the survey that lie within the 56 Central Valley DAUs selected for analysis.

While DWR includes some agricultural wells in its semi-annual water level survey, the vast majority of wells in the survey are used for irrigation. In order to further focus on these irrigation wells, only the wells located within the irrigated agricultural land-use types of each of the Central Valley DAUs were selected for analysis (see Figure 3.5). For example, Figure 3.8 shows the wells located within areas defined by an irrigated agricultural land-use type in DAU 163, Willows-Arbuckle. No attempt was made to differentiate between wells that were tapped in the surface unconfined aquifer and were recording the depth to water table and those recording the piezometric surface in a deeper confined aquifer. The fact that either surface lies close to the ground surface would detract from the attractiveness of this DAU, or any other DAU, for *in lieu* conjunctive use. Using the ArcView 3.2 Statistics tool, the average depth to water (DTW) reported in the Fall 1999 water level survey was found to be 35 feet in DAU 163. A similar calculation was carried out for each of the 56 Central Valley DAUs. While it may have been more accurate to contour the water level data in order to estimate the average depth to water, trial calculations on a few DAUs revealed that the results were not significantly different to merit the substantial increase in effort required for contouring. The results of this analysis for the entire Central Valley is presented in Section 4.0.

Figure 3.7: Location of DWR Water Level Survey Wells Located within the 56 Selected Central Valley DAUs

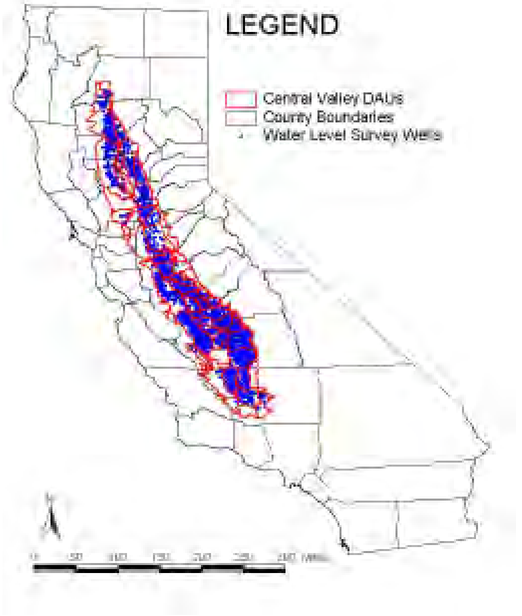
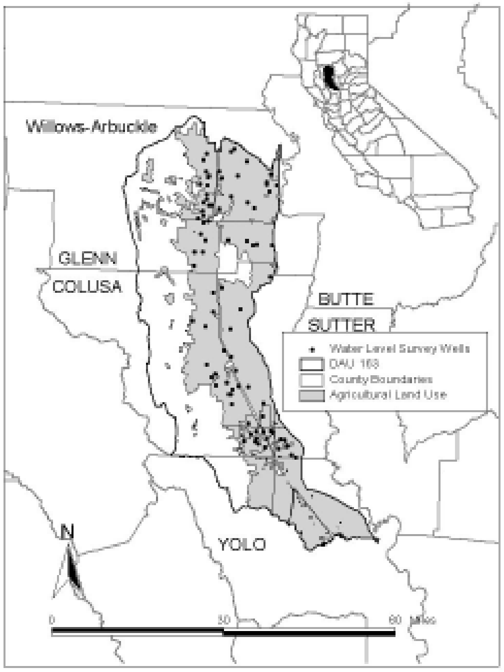


Figure 3.8: Location of DWR Water Level Survey Wells Located within Irrigated Agricultural Areas of DAU 163, Willows-Arbuckle



4.0 Results

Figures 4.1 through 4.3 present the results of the analysis to determine the current mix of surface water and groundwater utilization in DAUs located within the Sacramento River, San Joaquin River and Tulare Lake Hydrologic Regions. In each region the DAU have been sorted by the sum of the surface water (ASW) and groundwater (GSW) applied in the agricultural sector. The recorded value of evapotranspiration of applied water (ETAW) is also plotted on the left-hand volumetric scale. Calculated values of the irrigation efficiency (E) and agricultural surface water contribution (%SW) are plotted on the right-hand percent scale.

In examining these figures, the most attractive DAUs are those that utilize a mix of surface water and groundwater for irrigation, as this suggests that groundwater pumping could be replaced by *in lieu* deliveries of locally available surface water. The absolute amount of water used in agriculture is also important as it corresponds with the magnitude of the *in lieu* conjunctive use program that could occur. DAUs with low irrigation efficiencies are areas where improved water management might allow for a wider distribution of available surface water. DAUs in the San Joaquin River and Tulare Lake Hydrologic Regions with negative values of applied groundwater reflect the fact that AGW is calculated as a closure term in the water balance conducted for these regions combined with the fact that ASW exceeds ETAW in these units. DAUs without data are those for which no data could be obtained from the associated DWR regional office.

Figure 4.1: Relative Contribution of Surface Water and Groundwater to Irrigated Agriculture for DAUs in the Sacramento River Hydrologic Region

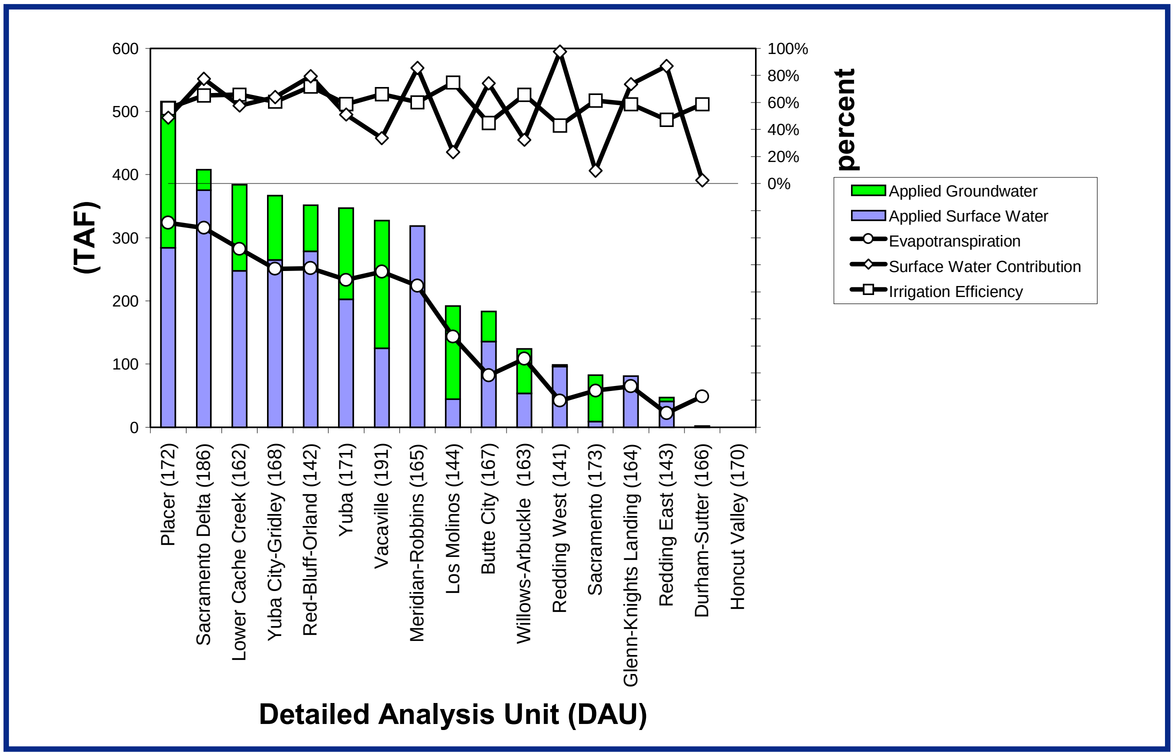


Figure 4.2: Relative Contribution of Surface Water and Groundwater to Irrigated Agriculture for DAUs in the San Joaquin River Hydrologic Region

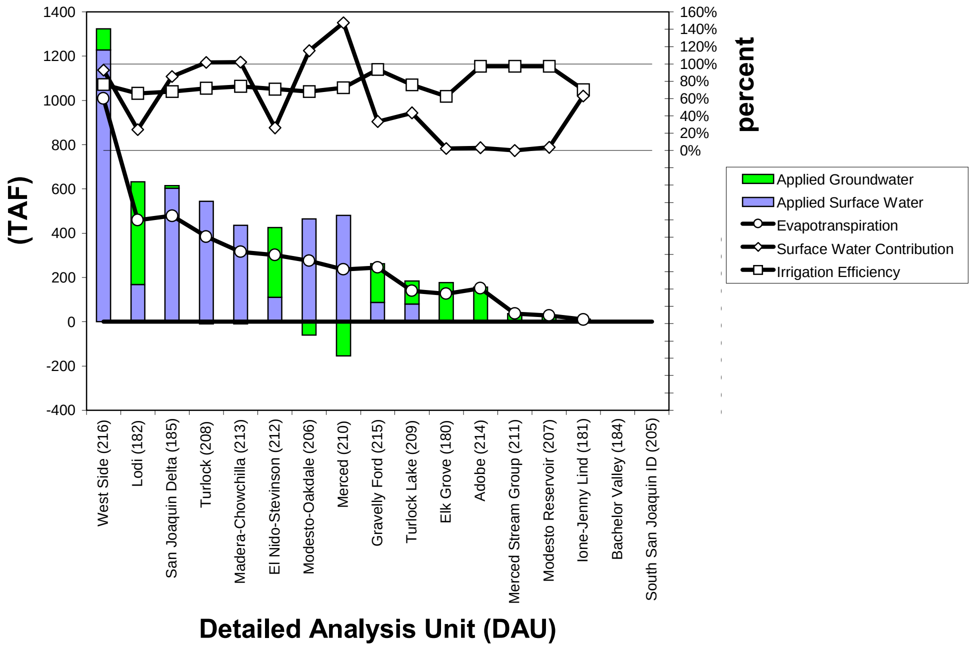
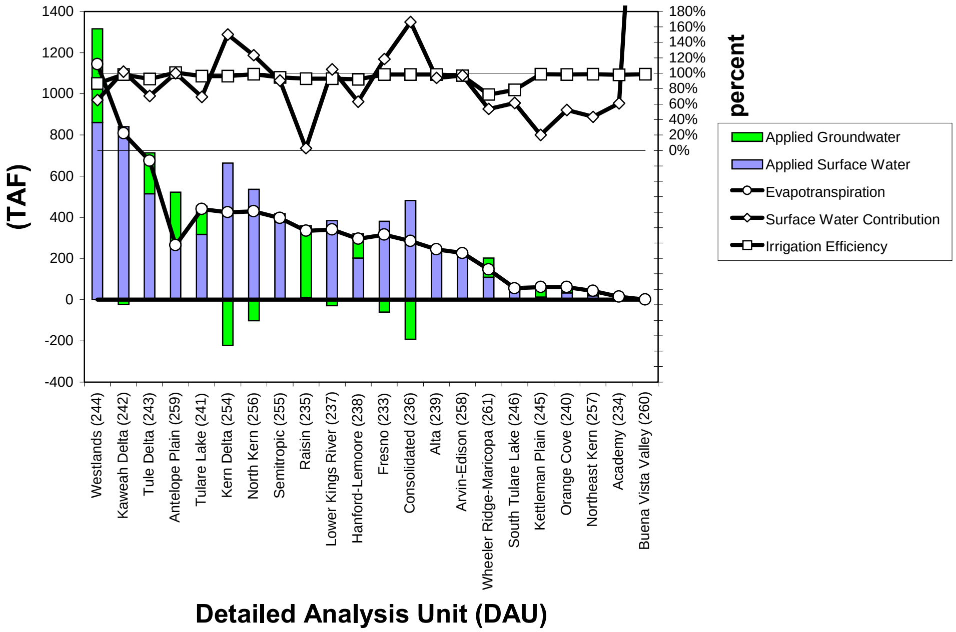


Figure 4.3: Relative Contribution of Surface Water and Groundwater to Irrigated Agriculture for DAUs in the Tulare Lake Hydrologic Region



Figures 4.4 through 4.6 contain the results of the spatial analysis on the proximity of unincorporated irrigated land to Federal, State and private water districts for the Sacramento River, San Joaquin River and Tulare Lake Regions. Only the area of the 1-mile buffers around water districts are included in these figures as these are the lands that could most easily receive surface water deliveries in lieu of groundwater pumping. Areas contained within the 2- and 3-mile buffers are reported in Appendix B, along with the data used to develop Figures 4.4 through 4.6. The DAUs are sorted by the amount of land in close proximity to Federal water districts in order to reflect the support that the USBR has provided to the effort. State water districts are not found within the Sacramento River Hydrologic Region, and the only one in the San Joaquin River Hydrologic Region, DAU 216 West Side, has virtually no unincorporated irrigated land in its immediate vicinity.

Figures 4.7 through 4.9 depict the results of the depth to water analysis for DAUs in the Sacramento River, San Joaquin River and Tulare Lake Hydrologic Regions. The very large DTW values observed in the Tulare Lake Hydrologic Region are probably due to the fact that many of the agricultural wells in this region are screened in the confined aquifer below the Corcoran Clay. A table summarizing the data found in these figures is summarized in Appendix C.

Figure 4.4: Unincorporated Irrigated Land within 1 Mile of Water Districts for DAUs Located within the Sacramento River Hydrologic Region

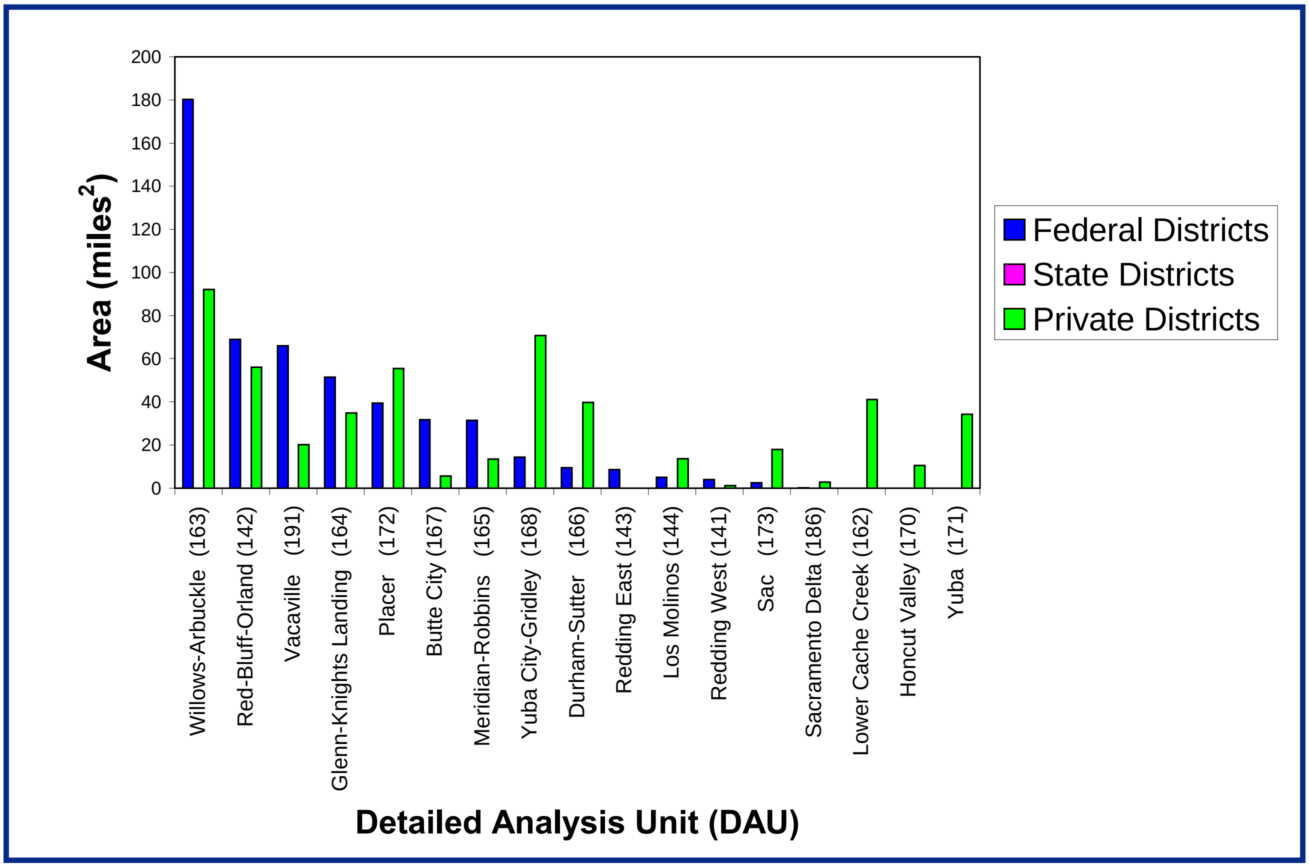


Figure 4.5: Unincorporated Irrigated Land within 1 Mile of Water Districts for DAUs Located within the San Joaquin River Hydrologic Region

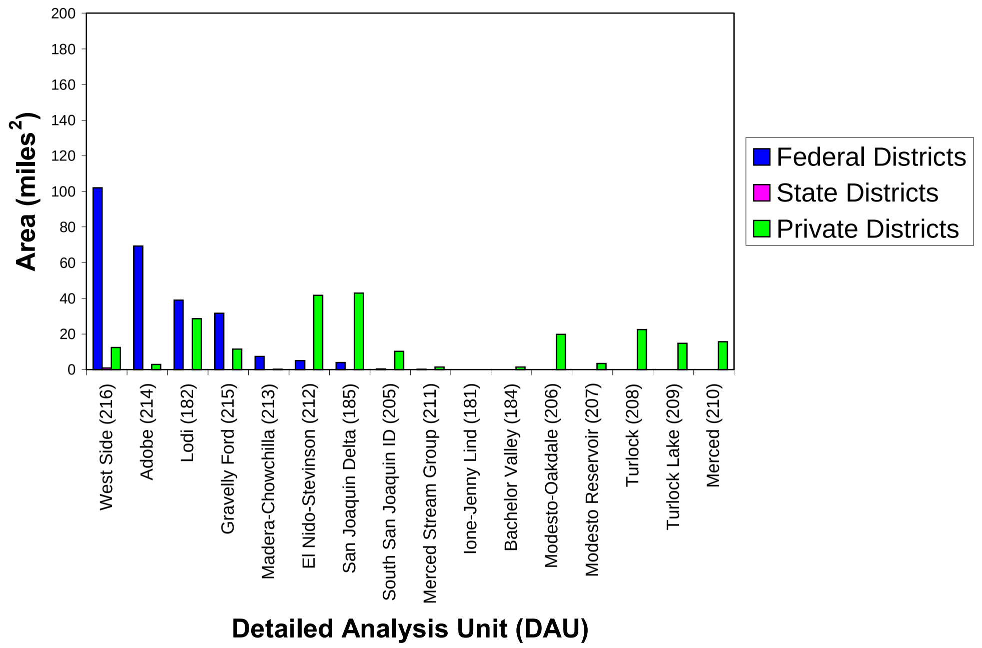


Figure 4.6: Unincorporated Irrigated Land within 1 Mile of Water Districts for DAUs Located within the Tulare Lake Hydrologic Region

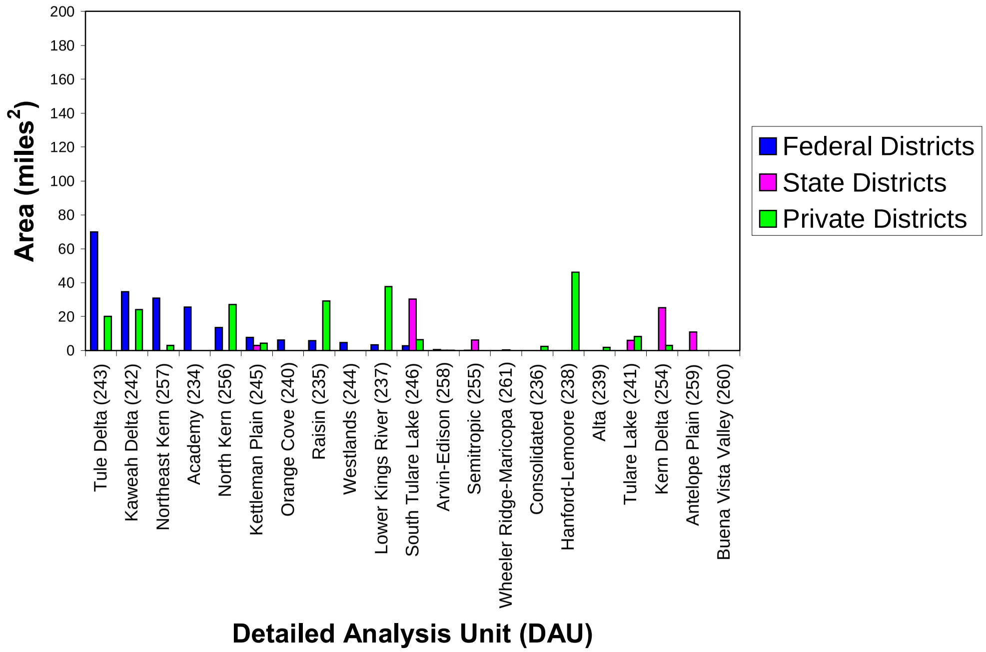


Figure 4.7: DTW in DAUs in the Sacramento River Hydrologic Region

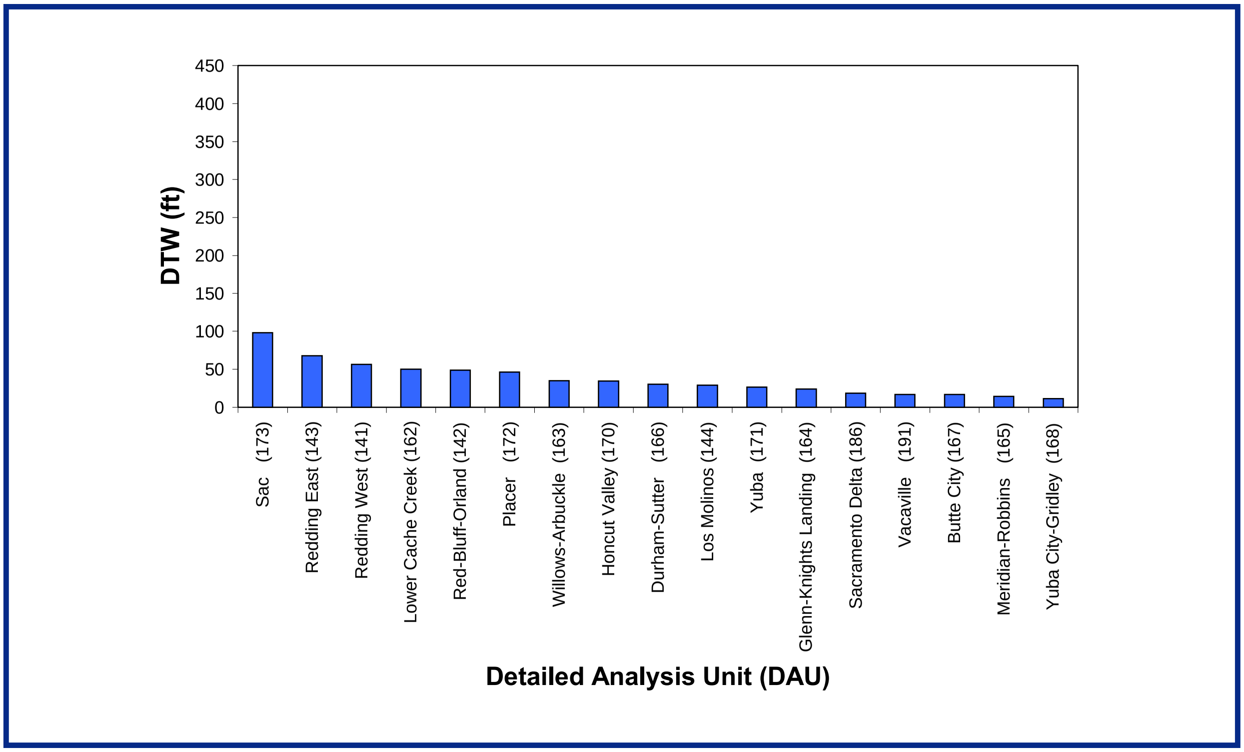


Figure 4.8: DTW in DAUs in the San Joaquin River Hydrologic Region

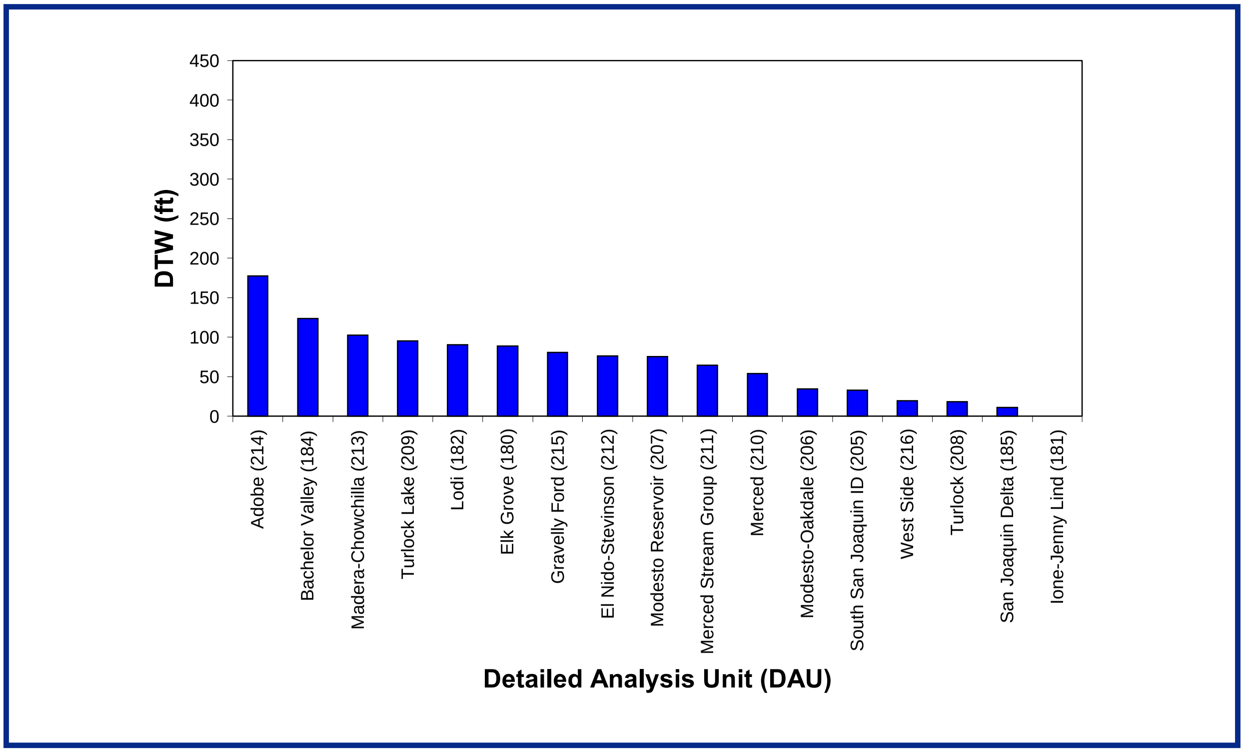
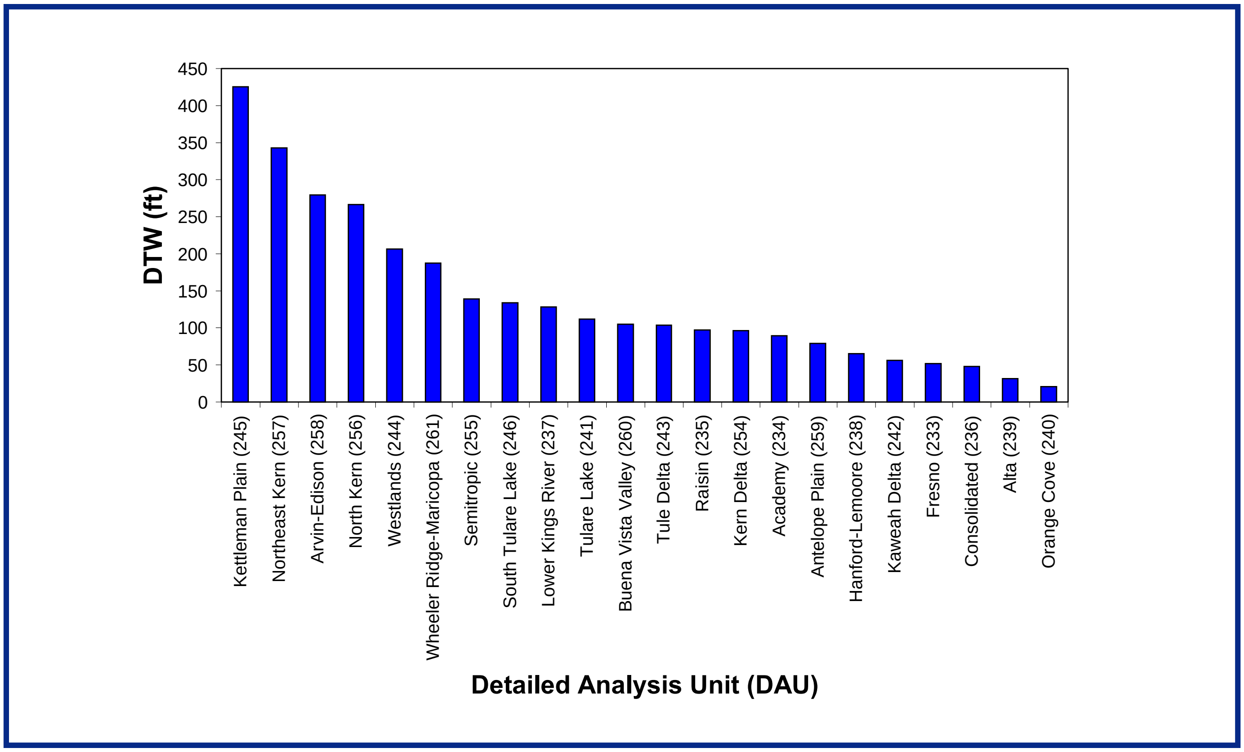


Figure 4.9: DTW in DAUs in the Tulare Lake Hydrologic Region



5.0 Analysis and Conclusions

Based on the results of analysis of the three evaluation criteria, several DAUs in each of the Hydrologic Regions emerge as attractive candidates for *in lieu* conjunctive water management. The first filter that was applied to identifying target DAUs was the mix of surface water and groundwater used in the agricultural sector. Table 5.1 includes DAUs where 20 to 70% of irrigation water is supplied by groundwater pumping. This level has been established because it reflects the fact that there is a significant reliance on groundwater pumping in the vicinity of the water districts endowed with locally important surface water rights that could potentially be managed to offset some groundwater pumping. The DAUs in Table 5.1 have also been screened to include only those that reported more than 20 TAF of total agricultural water use. Areas with smaller amounts of total agricultural water use were eliminated because they do not represent a significant opportunity from the perspective of system-wide conjunctive water management planning. The DAUs shown in bold have an estimated irrigation efficiency of less than 70%. These are areas where water management improvements may create the opportunity to expand the delivery of existing surface water supplies, although detailed analysis will be required to evaluate this opportunity since some percentage of the water not consumed by crops may be collected and used by other irrigators.

The second filter allied to the results was the proximity of water districts whose surface water delivery infrastructure would likely be extended to supply surface water in lieu of groundwater pumping.

Those DAUs listed in Table 5.1 with more than 10 miles^2 of unincorporated irrigated land within 1 mile of either Federal, State or private water districts in the DAU are listed in Table 5.2.

Table 5.1: Central Valley DAUs with > 20% and < 70% Reliance on Groundwater Pumping in the Agricultural Sector and > 20 TAF of Total Agricultural Water Use

DAU	Hydrologic Region	SW Contribution (%)	GW Contirbution (%)	ASW + AGW (TAF)
Red-Bluff-Orland (142)	Sacramento River	79.4%	20.6%	351.2
Lower Cache Creek (162)	Sacramento River	57.7%	42.3%	383.6
Willows-Arbuckle (163)	Sacramento River	32.4%	67.6%	123.9
Glenn-Knights Landing (164)	Sacramento River	73.5%	26.5%	80.8
Vacaville (191)	Sacramento River	33.6%	66.4%	327.0
Butte City (167)	Sacramento River	74.1%	25.9%	183.3
Yuba City-Gridley (168)	Sacramento River	63.9%	36.1%	366.6
Yuba (171)	Sacramento River	51.1%	48.9%	347.1
Placer (172)	Sacramento River	48.8%	51.2%	515.6
Sacramento Delta (186)	Sacramento River	77.5%	22.5%	407.8
Turlock Lake (209)	San Joaquin	43.4%	56.6%	184.2
Gravelly Ford (215)	San Joaquin	33.6%	66.4%	261.7
Hanford-Lemoore (238)	Tulare Lake	63.3%	36.7%	320.4
Orange Cove (240)	Tulare Lake	52.4%	47.6%	61.6
Tulare Lake (241)	Tulare Lake	69.2%	30.8%	453.8
Tule Delta (243)	Tulare Lake	70.7%	29.3%	712.8
Westlands (244)	Tulare Lake	65.4%	34.6%	1316.8
South Tulare Lake (246)	Tulare Lake	61.4%	38.6%	70.5
Northeast Kern (257)	Tulare Lake	43.5%	56.5%	42.8
Wheeler Ridge-Maricopa (261)	Tulare Lake	53.8%	46.2%	202.2

Table 5.2: Central Valley DAUs with > 10 Miles^2 of Unincorporated Irrigated Land within 1 Mile of Federal, State or Private Water Districts

DAU name	Hydrologic Region	Federal (miles^2)	State (miles^2)	Private (miles^2)
Red-Bluff-Orland (142)	Sacramento River	69.0	0.0	56.0
Lower Cache Creek (162)	Sacramento River	0	0.0	41.0
Willows-Arbuckle (163)	Sacramento River	180.3	0.0	92.1
Glenn-Knights Landing (164)	Sacramento River	51.5	0.0	34.9
Vacaville (191)	Sacramento River	66.0	0.0	20.1
Butte City (167)	Sacramento River	31.8	0.0	5.7
Yuba City-Gridley (168)	Sacramento River	14.3	0.0	70.8
Yuba (171)	Sacramento River	0	0.0	34.2
Placer (172)	Sacramento River	39.4	0.0	55.6
Turlock Lake (209)	San Joaquin	0.0	0.0	14.7
Gravelly Ford (215)	San Joaquin	31.7	0.0	11.4
Hanford-Lemoore (238)	Tulare Lake	0.0	0.0	46.2
Tule Delta (243)	Tulare Lake	69.9	0.0	20.1
South Tulare Lake (246)	Tulare Lake	2.7	30.2	6.3
Northeast Kern (257)	Tulare Lake	30.8	0.0	3.0

Finally, for the DAUs listed in Table 5.2, the depth to water evaluation criterion was applied. Table 5.3 lists those DAUs where the estimated depth to water in agricultural wells was at least 20 feet below ground surface. This value was selected to represent the fact that higher water levels associated with *in lieu* conjunctive water management should not be allowed to rise too close to the ground surface. If the starting water level is less than 20 feet, there may not be much opportunity to increase the amount of groundwater storage within the DAU.

Table 5.3: Central Valley DAUs where the Estimated Depth to Water in Agricultural Wells is at Least 20 Feet Below Ground Surface

DAU name	Hydrologic Region	DTW (ft)
Red-Bluff-Orland (142)	Sacramento River	48.9
Lower Cache Creek (162)	Sacramento River	50.3
Willows-Arbuckle (163)	Sacramento River	35
Glenn-Knights Landing (164)	Sacramento River	23.9
Yuba (171)	Sacramento River	26.4
Placer (172)	Sacramento River	46.1
Turlock Lake (209)	San Joaquin	95.3
Gravelly Ford (215)	San Joaquin	80.6
Hanford-Lemoore (238)	Tulare Lake	65.2
Tule Delta (243)	Tulare Lake	103.8
South Tulare Lake (246)	Tulare Lake	134.1
Northeast Kern (257)	Tulare Lake	343

The map in Figure 5.1 depicts the location of the Central Valley DAUs that have been identified as attractive locations for *in lieu* conjunctive water management based on the application of the three selected evaluation criteria. This map suggests that opportunities for *in lieu* conjunctive water management exist in all three of the Hydrologic Regions in the Central Valley, although the Sacramento River and Tulare Lake regions have larger amounts of land that could be easily incorporated into a program (see Table 5.2).

Based on the values of the various evaluation criteria, it is possible to develop a very rough estimate of the scale of the *in lieu* conjunctive use program that could be implemented in the DAUs identified in the screening process. This can be done in two ways. First the estimated available aquifer storage can be calculated as the product of the difference between the depth to water and a plane 10 feet below the land surface and the area of land within 1 mile of water districts adjusted by a specific yield in the case of wells with a DTW of less than 100 ft (assume 0.1) and the specific storage in wells with a DTW in excess of 100 ft (assume 0.01). The second estimate can be made by assuming that up to 10% of the allied surface water in a DAU could be used to offset up to 50% of groundwater pumping. The results of this analysis are found in Table 5.4. The first number is a proxy for the total available storage while the second number is a proxy for the amount of water that could be delivered to storage in a typical water year. Even given the coarse nature of these calculations it is evident that the scale of potential *in lieu* conjunctive water management opportunities in the Central Valley is very substantial. Further analysis of aquifer characteristics and water supply opportunities in these DAUs would help to refine these estimates.

Figure 5.1: Locations of Promising DAUs in the Central Valley

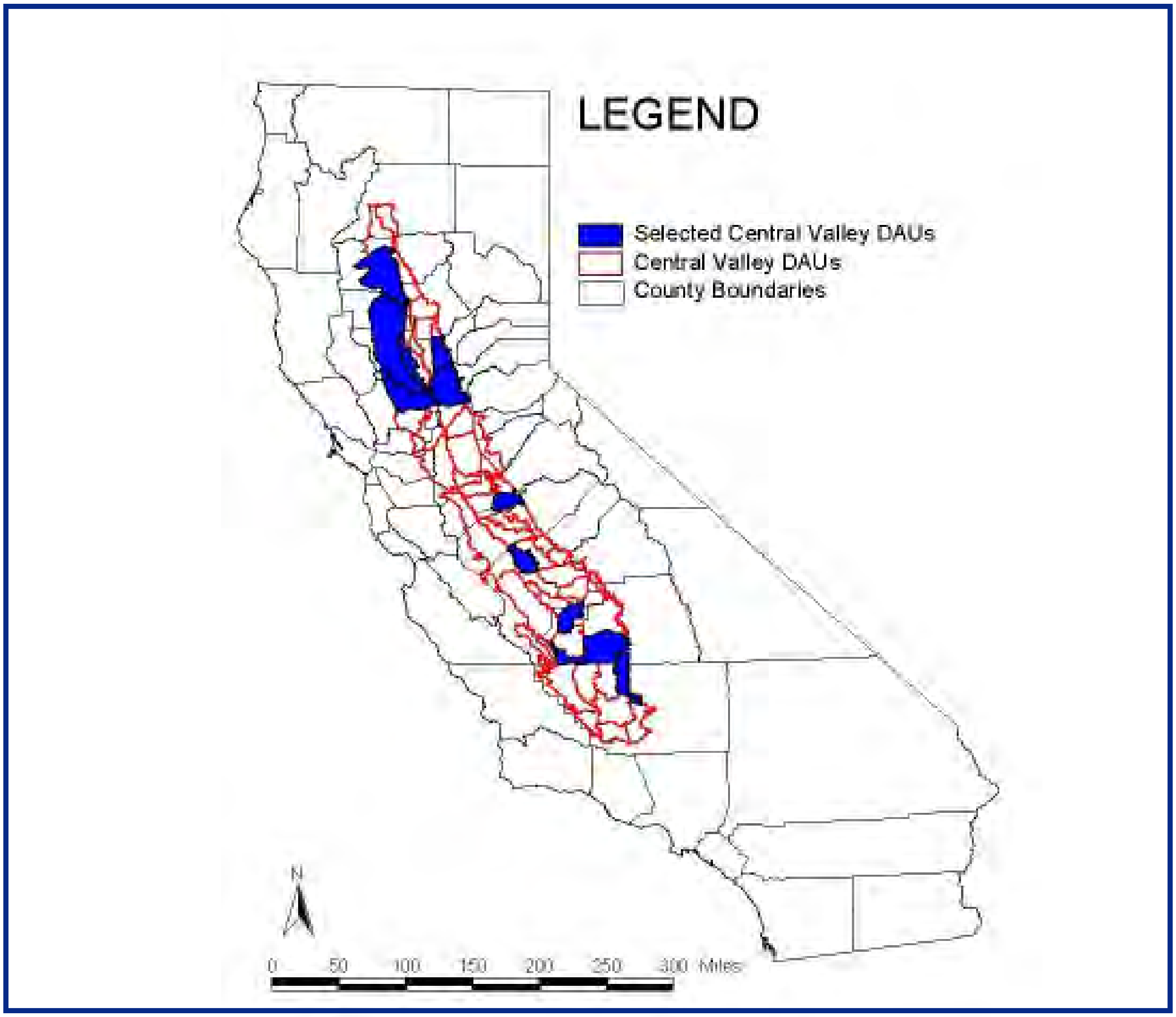


Table 5.4: Analysis of the Scale of Potential *In Lieu* Programs in the Central Valley

		Area within 1 mile				Estimated Available Storage			
DAU name	**Hydrologic Region**	**Federal (miles^2)**	**State (miles^2)**	**Private (miles^2)**	**DTW (ft)**	**Federal (TAF)**	**State (TAF)**	**Private (TAF)**	**Available Water (TAF)**
Red-Bluff-Orland (142)	Sacramento River	69.0	0.0	56.0	48.9	343.74	0.0	278.87	36.2
Lower Cache Creek (162)	Sacramento River	0	0.0	41.0	50.3	0.00	0.0	211.72	81.1
Willows-Arbuckle (163)	Sacramento River	180.3	0.0	92.1	35	577.09	0.0	294.57	41.9
Glenn-Knights Landing (164)	Sacramento River	51.5	0.0	34.9	23.9	91.66	0.0	62.01	10.7
Yuba (171)	Sacramento River	0	0.0	34.2	26.4	0.00	0.0	71.90	84.9
Placer (172)	Sacramento River	39.4	0.0	55.6	46.1	181.87	0.0	256.71	132.0
Turlock Lake (209)	San Joaquin	0.0	0.0	14.7	95.3	0.00	0.0	160.46	52.1
Gravelly Ford (215)	San Joaquin	31.7	0.0	11.4	80.6	286.03	0.0	103.33	86.9
Hanford-Lemoore (238)	Tulare Lake	0.0	0.0	46.2	65.2	0.00	0.0	326.58	58.9
Tule Delta (243)	Tulare Lake	69.9	0.0	20.1	103.8	4.20	0.0	1.21	104.4
South Tulare Lake (246)	Tulare Lake	2.7	30.2	6.3	134.1	0.21	2.40	0.50	13.6
Northeast Kern (257)	Tulare Lake	30.8	0.0	3.0	343	6.57	0.0	0.64	12.1
					Total =	**790.87**	**24.01**	**900.82**	**209.39**

Given the magnitude of the potential for *in lieu* conjunctive water management in the Central Valley, this component of a system-wide conjunctive water management strategy certainly merits further consideration. Information on this opportunity will be factored into future analyses conducted as part of this series, most notably, the evaluation of the potential for integrating conjunctive use into reservoir re-operation strategies that are also intended to enhance downstream fluvial processes, the “gaming” analysis of a series of conjunctive use configurations in the Central Valley, the economic optimization analysis, and the final feasibility study of and strategic plan for the initiative. In conclusion, however, even taken as a stand-alone piece of research, this analysis suggests that *in lieu* conjunctive water management can contribute to enhancing the performance of Federal, State and private surface water supplies in the coming decades.

6.0 References

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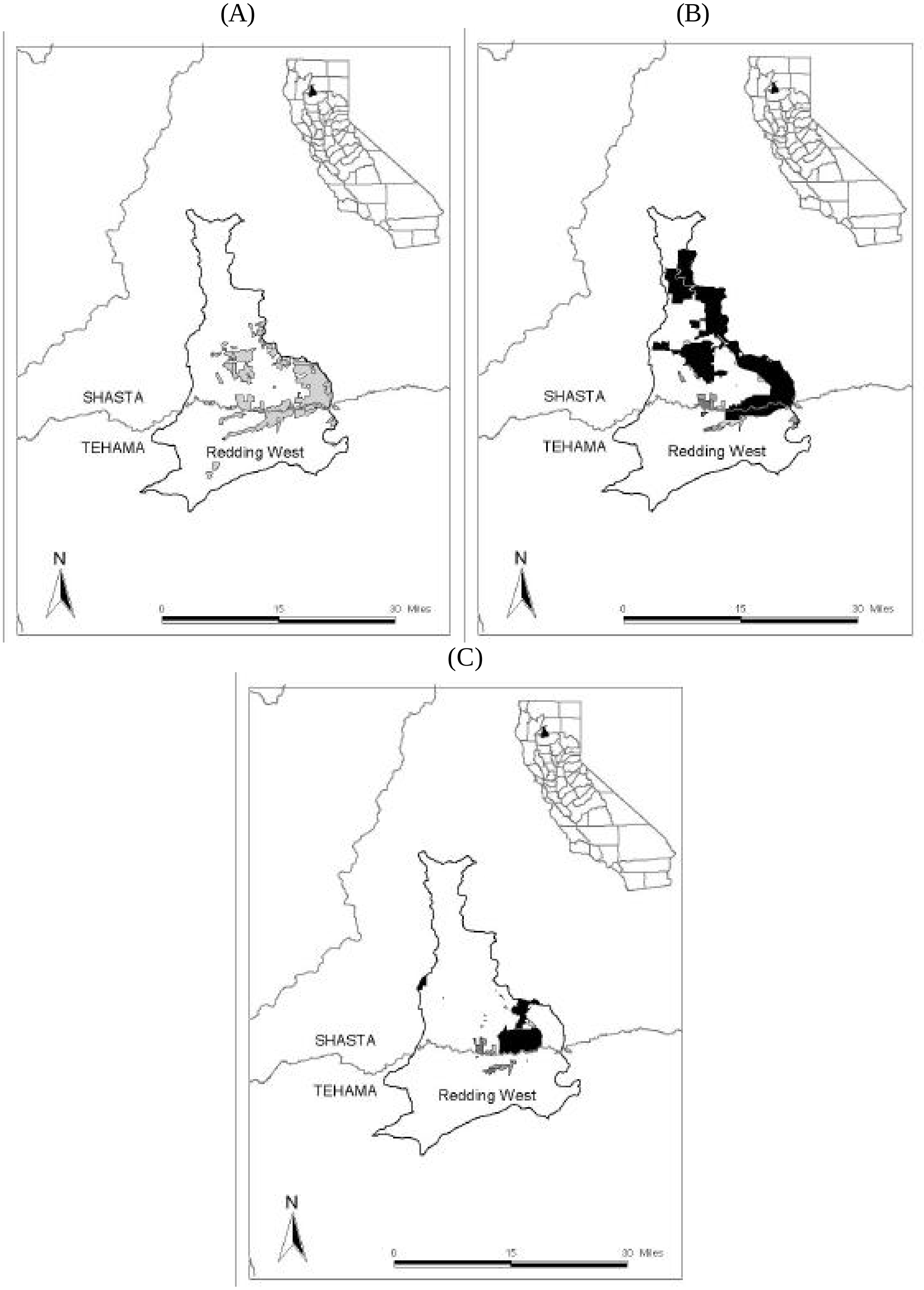
Appendix A:

Maps Depicting the Spatial Analysis Conducted to Determine the Amount of Unincorporated Irrigated Land Located within 1, 2 and 3 Miles of the Federal, State and Private Water Districts Found in the 56 Central Valley Detailed Analysis Units

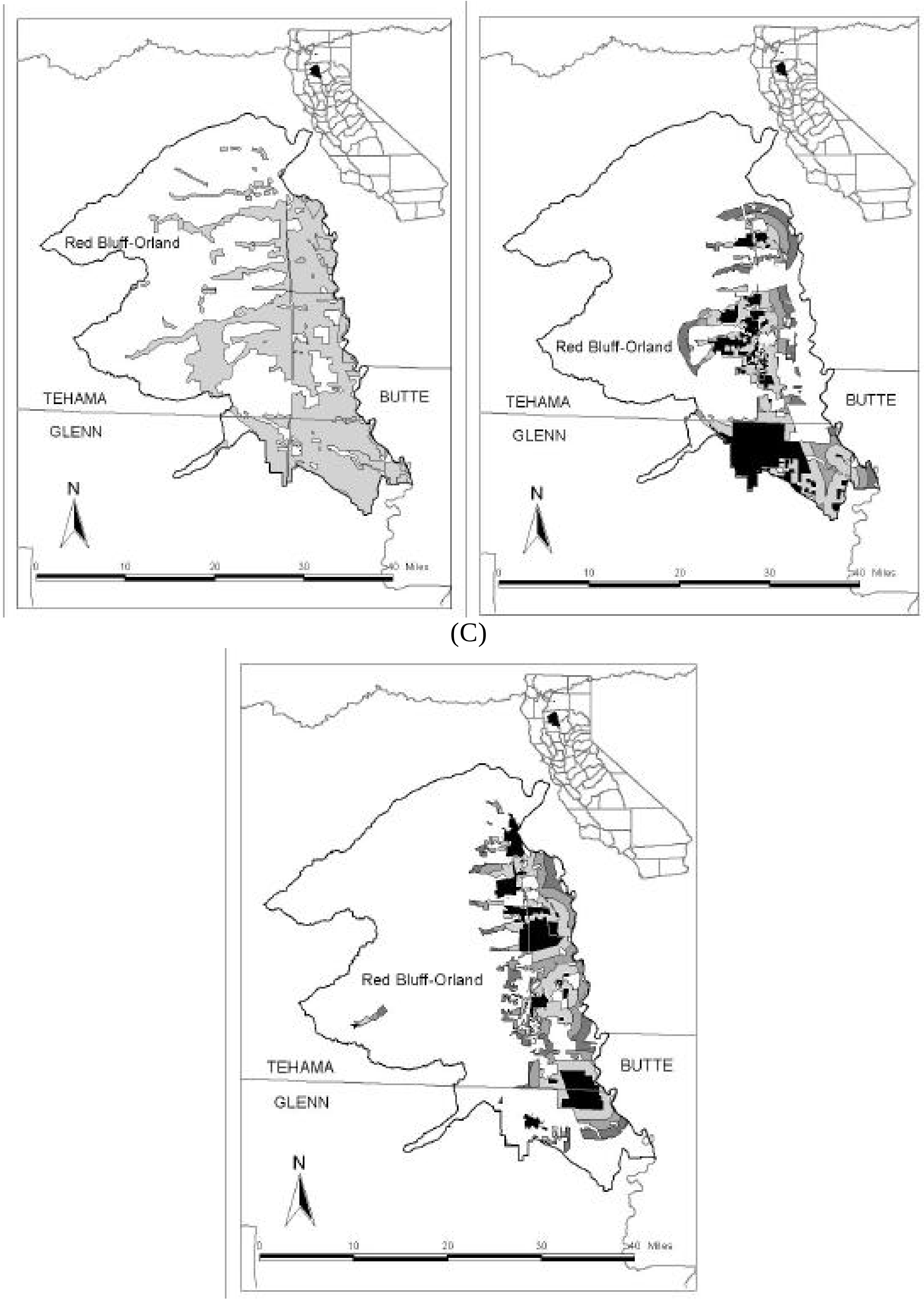
Figure A.1: DAU 141, Redding West, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (C)


(A)

(B)

(C)

Figure A.2: DAU 142, Red Bluff-Orland, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A) **(B)**

(C)

Figure A.3: DAU 143, Redding East, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B)

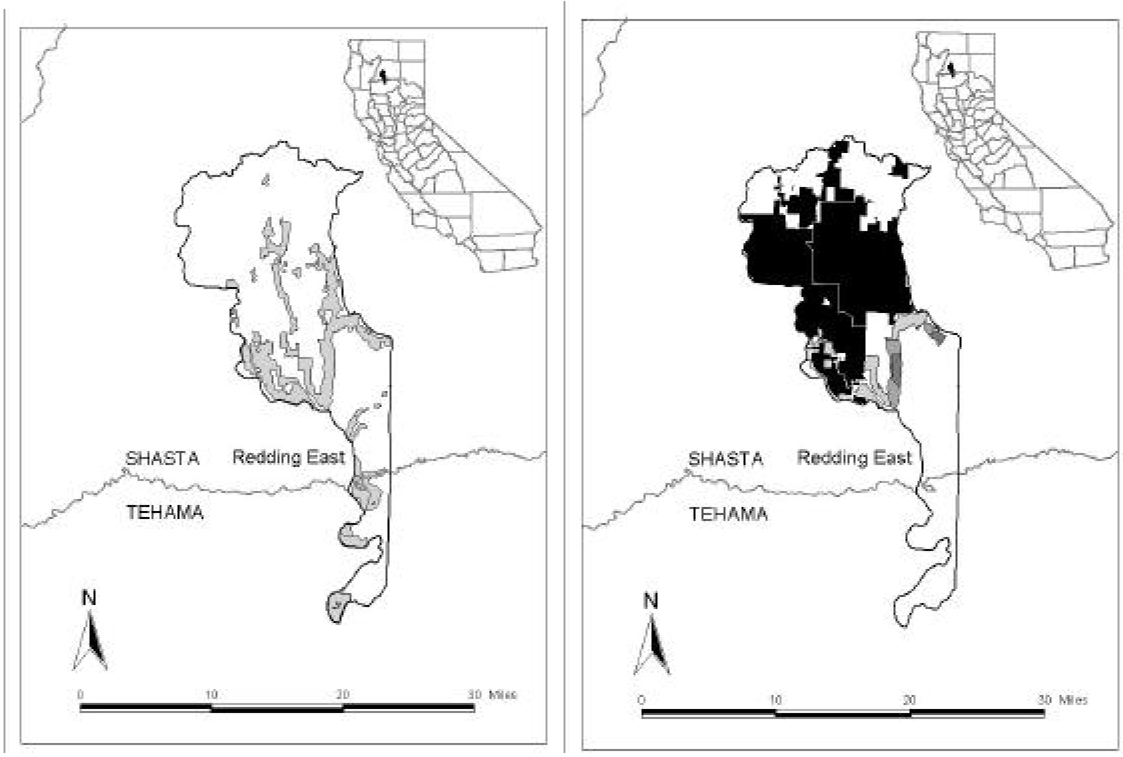
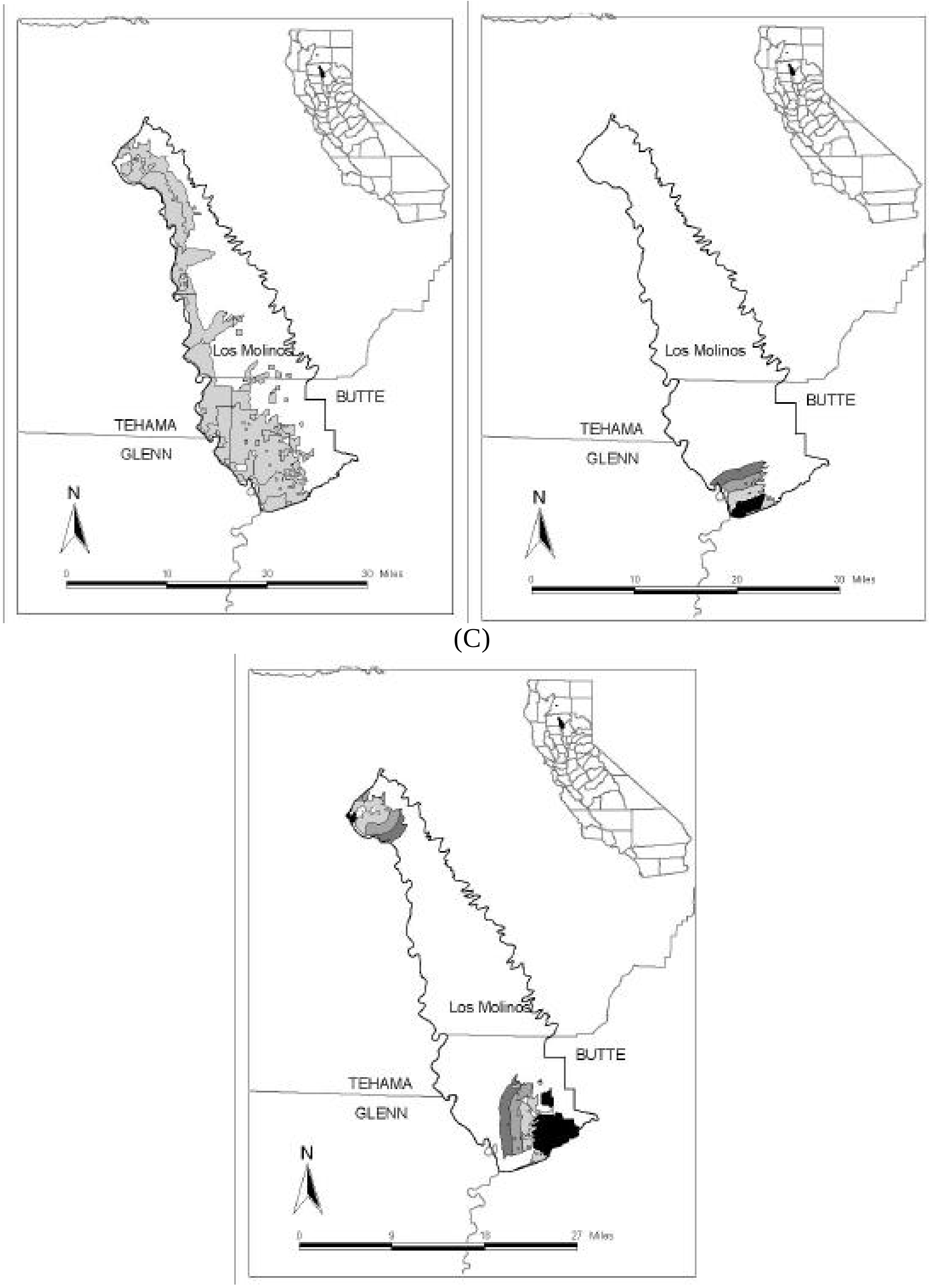

(A)
(B)

Figure A.4: DAU 144, Los Molinos, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A)

(B)

(C)

Figure A.5: DAU 162, Lower Cache Creek, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)

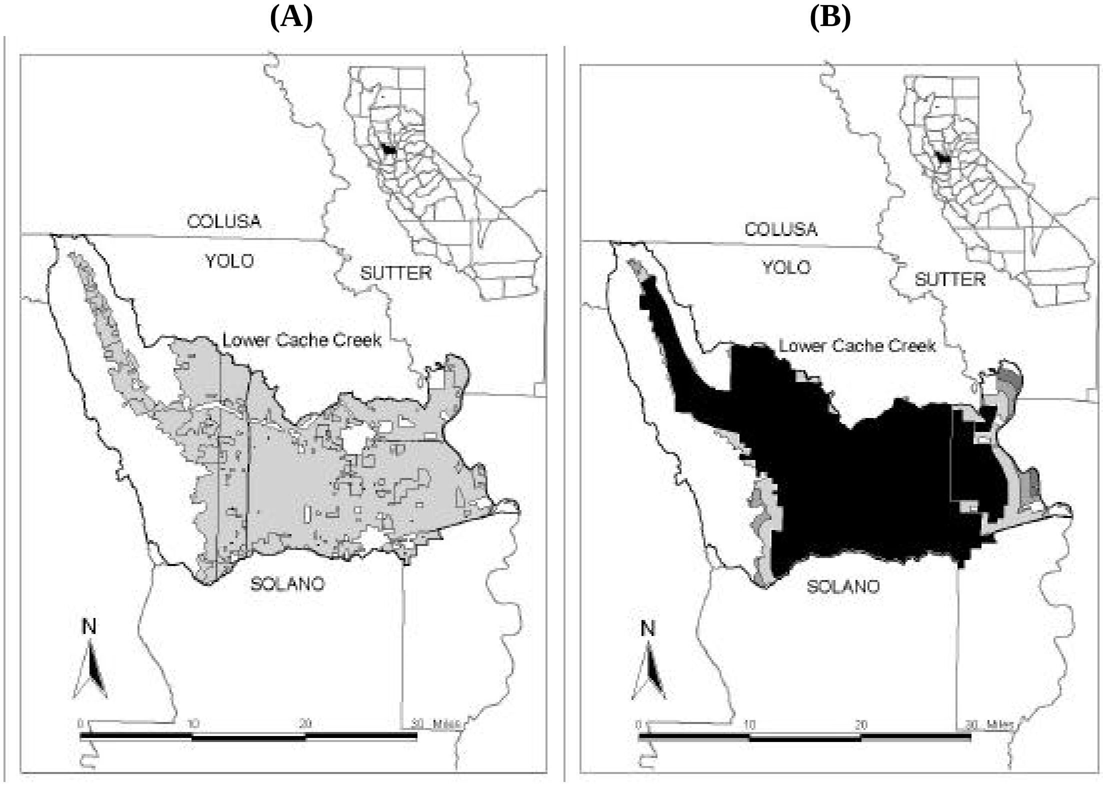

(A) (B)

Figure A.6: DAU 163, Willows-Arbuckle, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

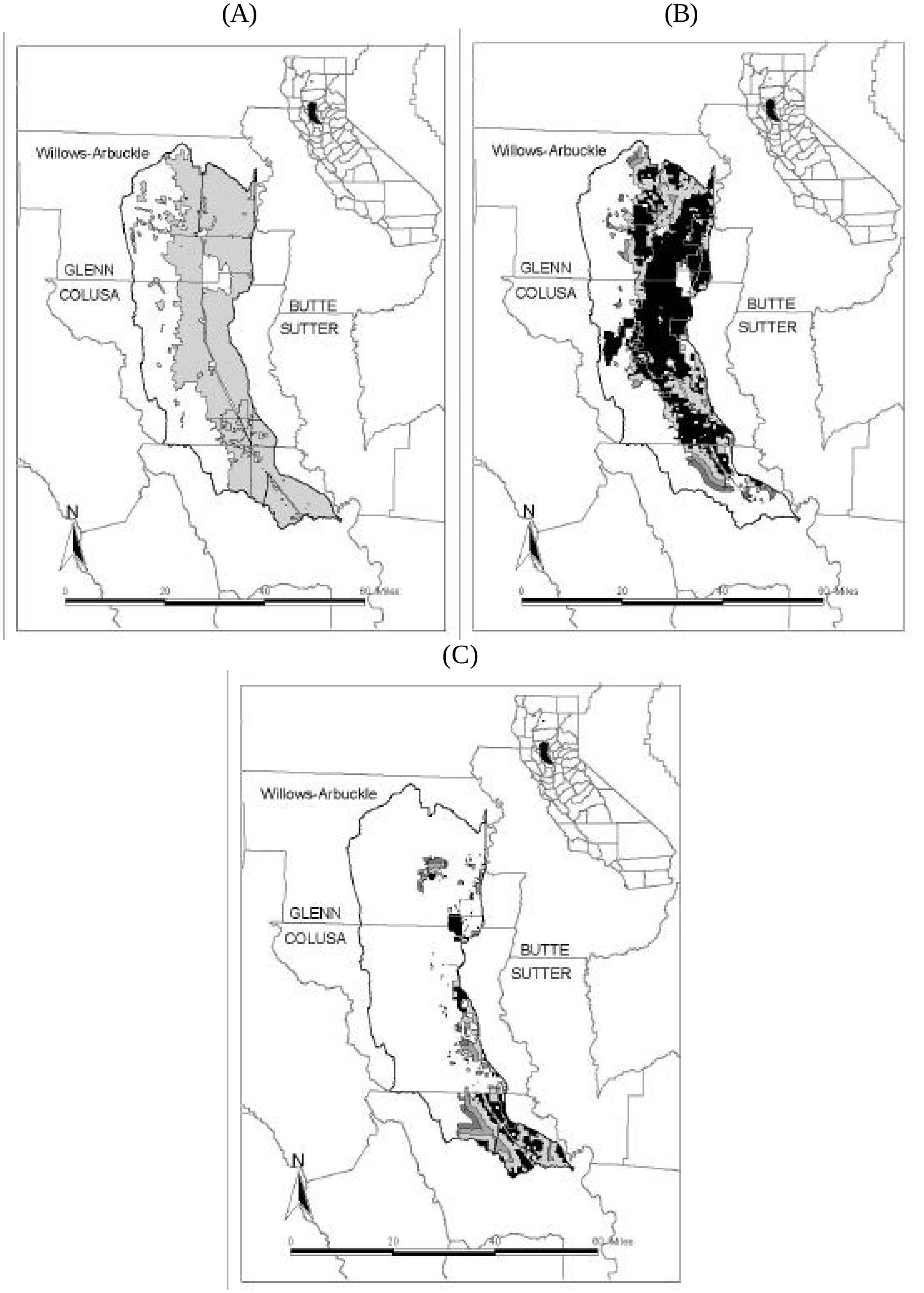

(A)
(B)
(C)

Figure A.7: DAU 164, Glenn-Knights Landing, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

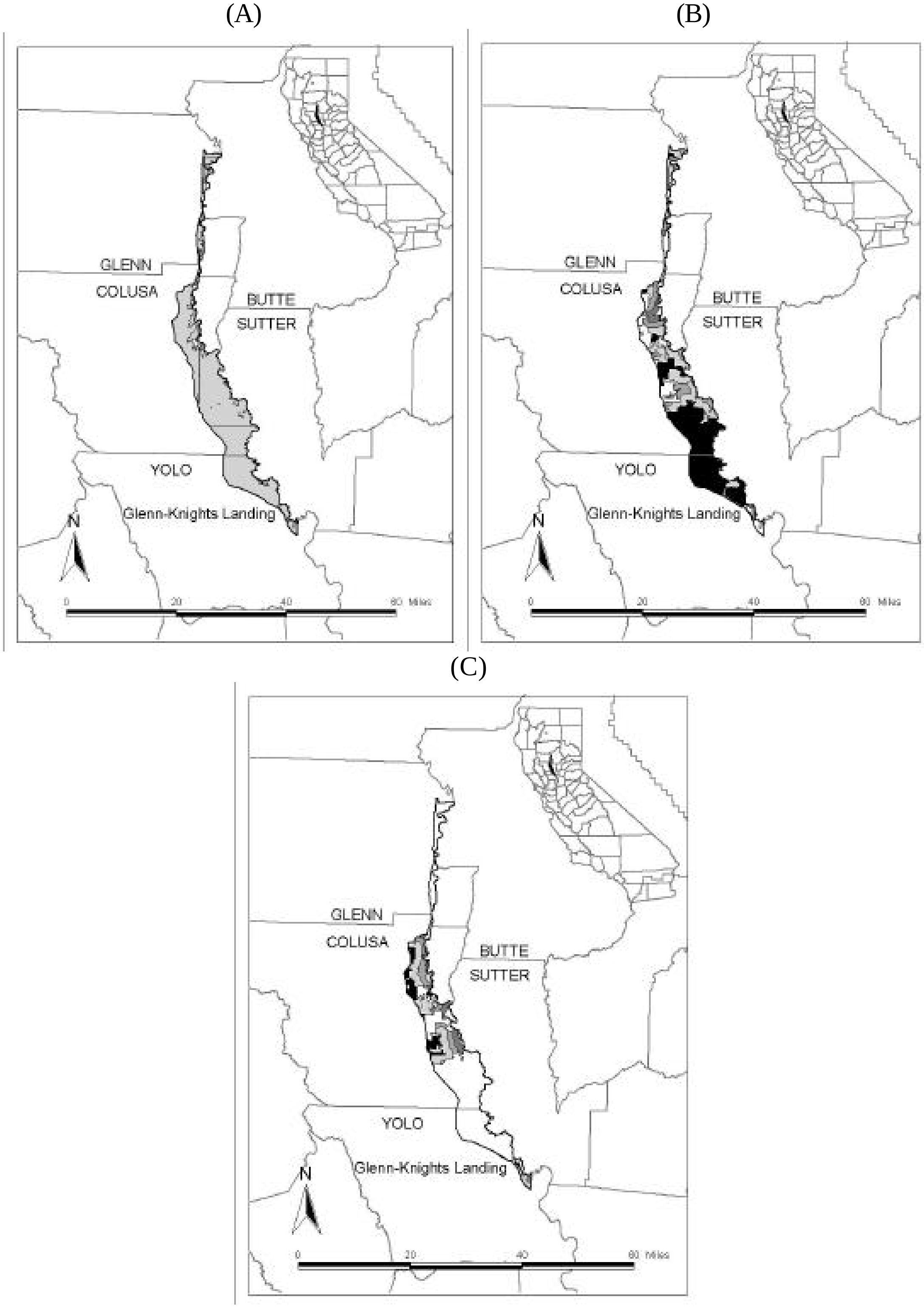

(A) (B) (C)

Figure A.8: DAU 165, Meridian-Robbins, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

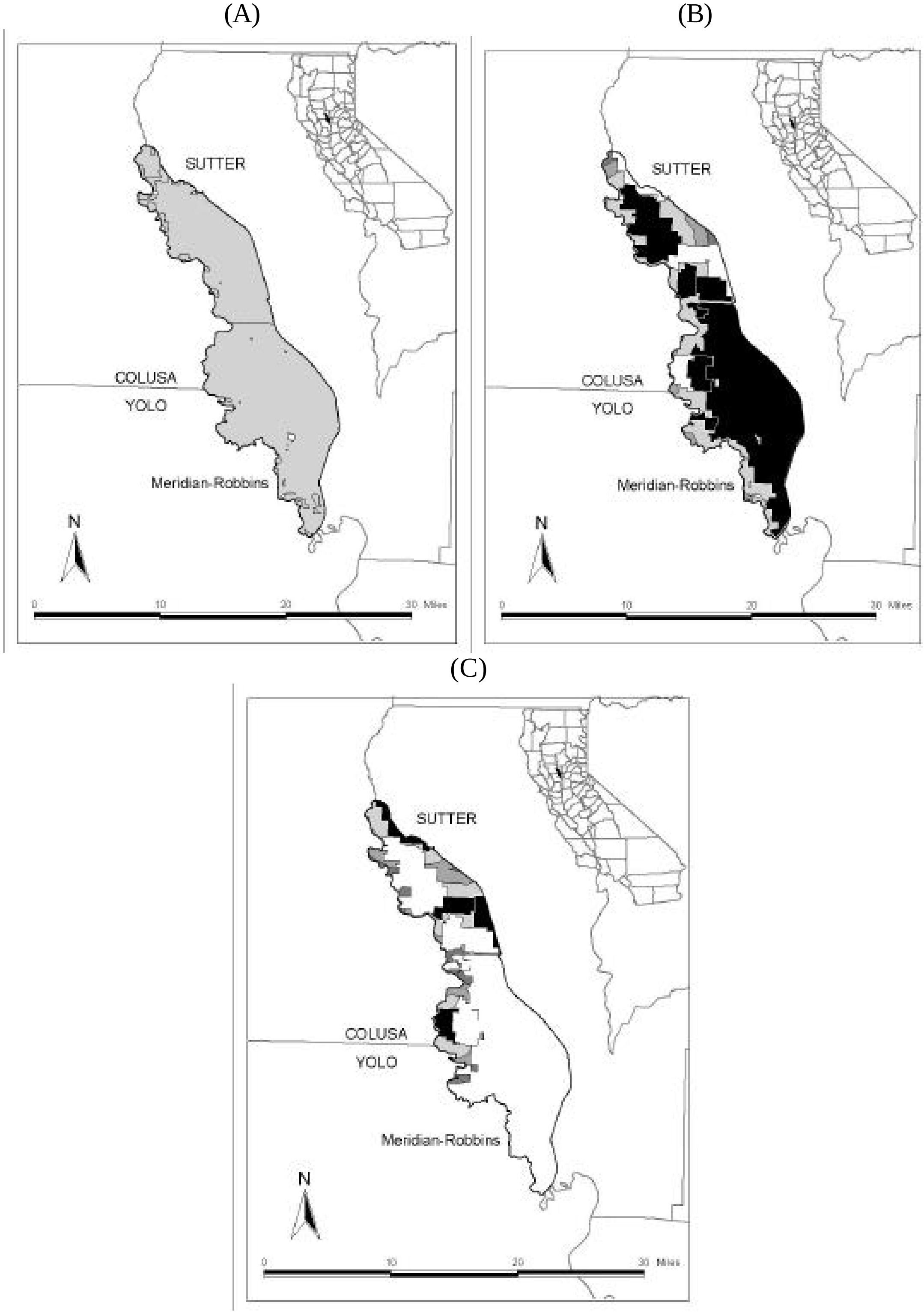
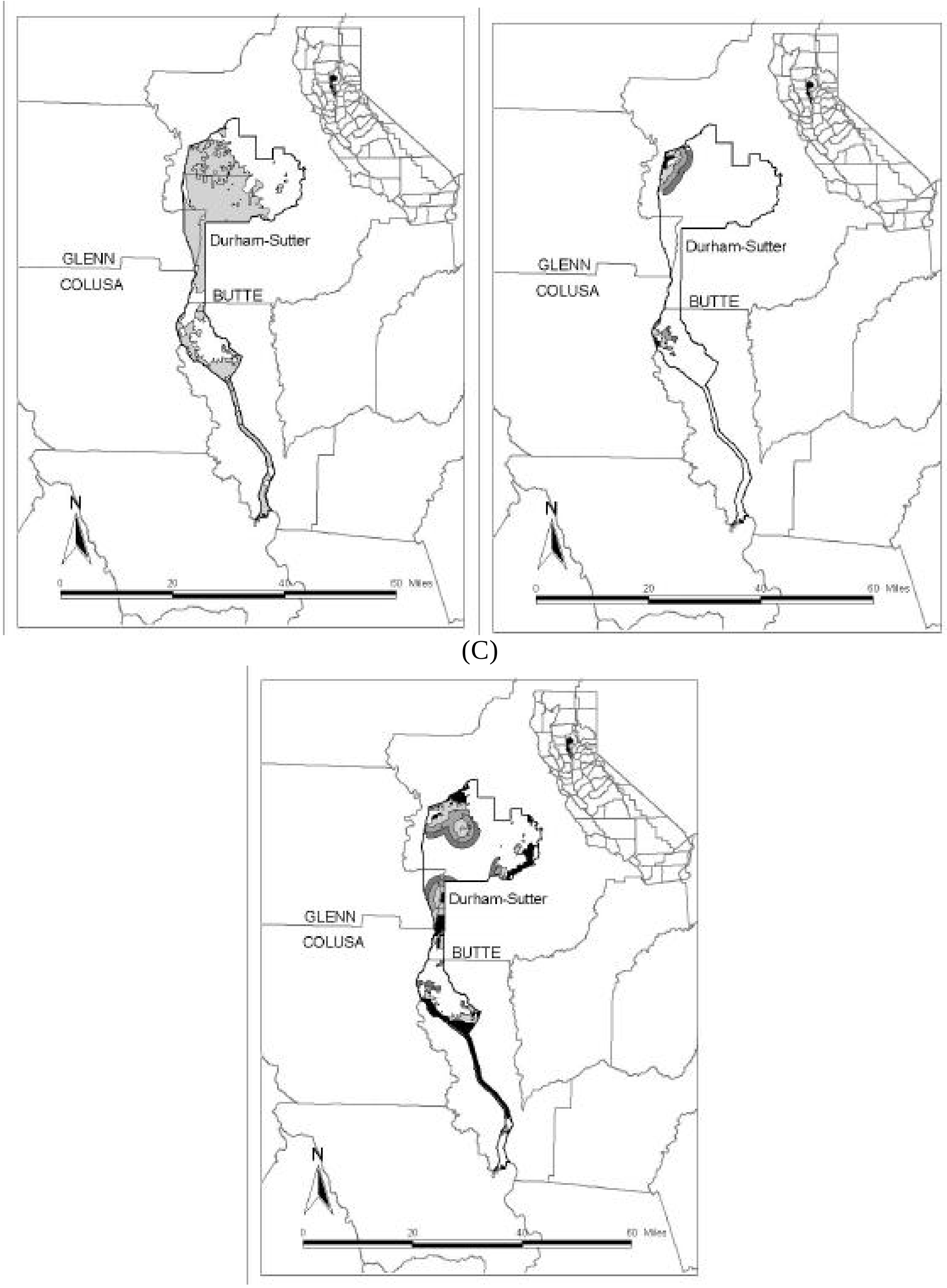


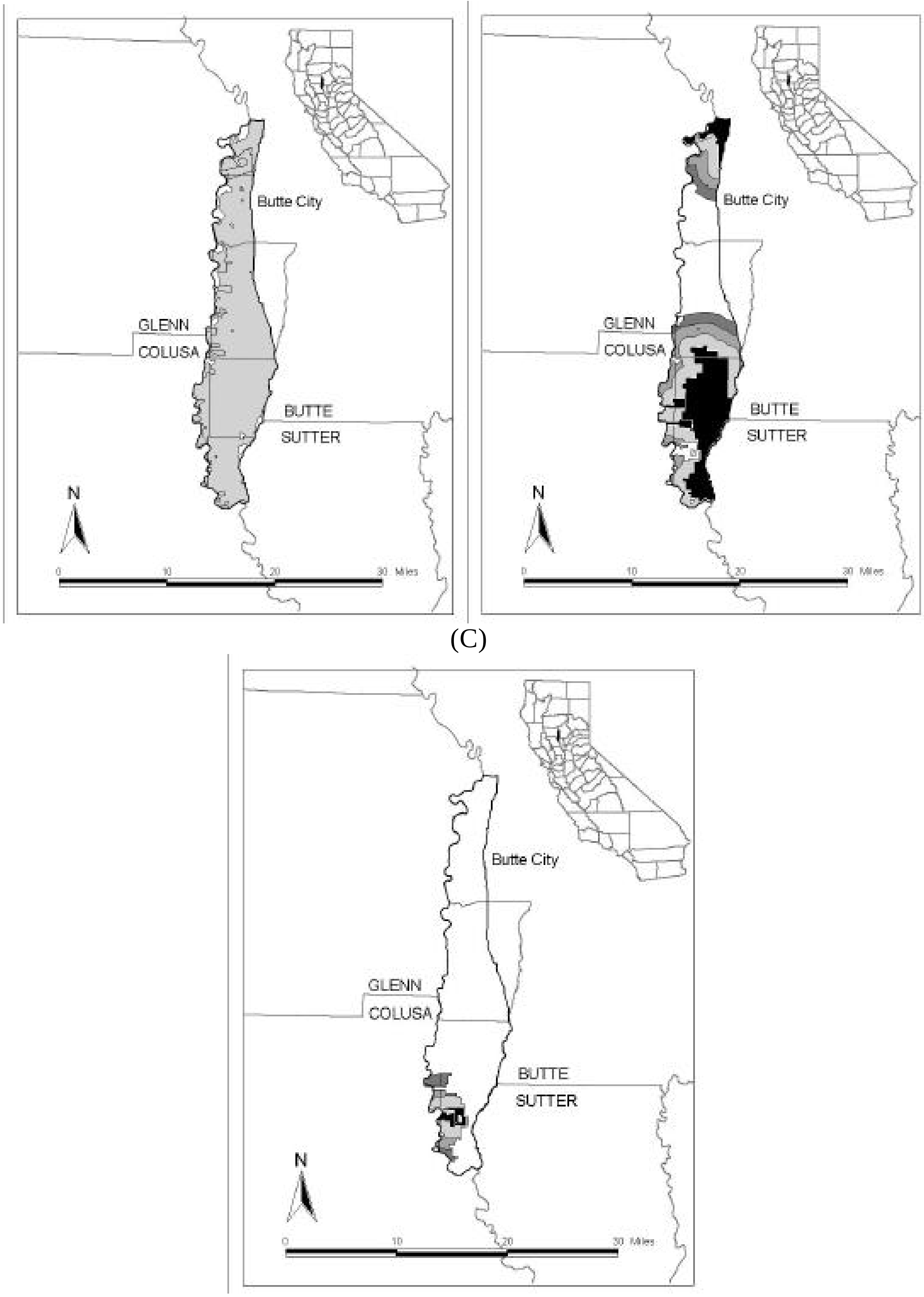
Figure A.9: DAU 166, Durham-Sutter, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)


(A)

(B)

(C)

Figure A.10: DAU 167, Butte City, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A)

(B)

(C)

Figure A.11: DAU 168, Yuba City-Gridley, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

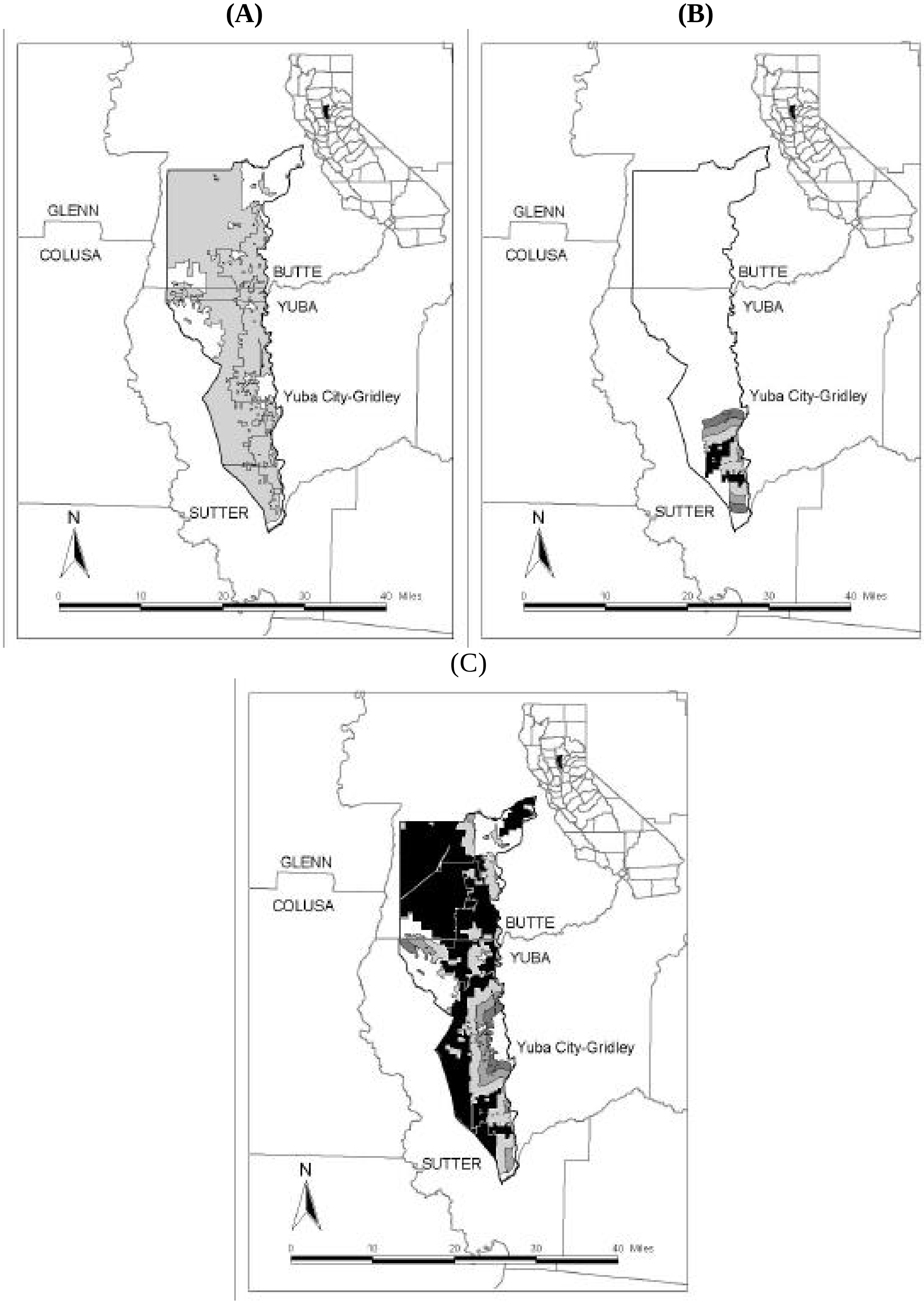
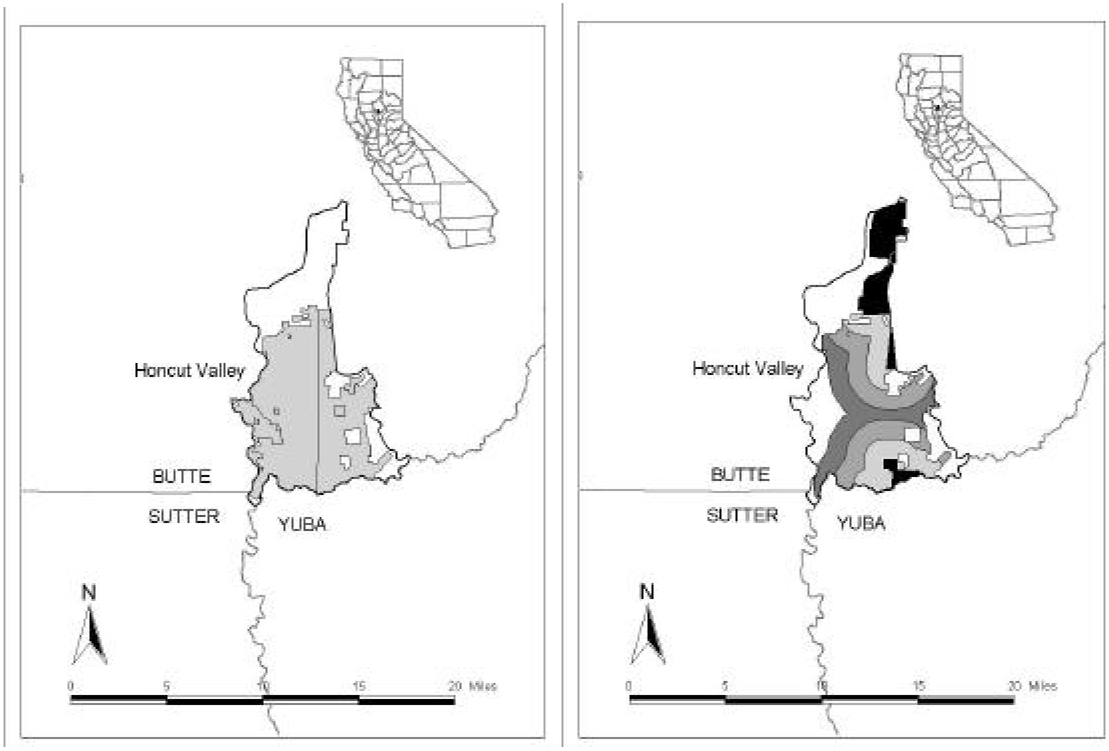
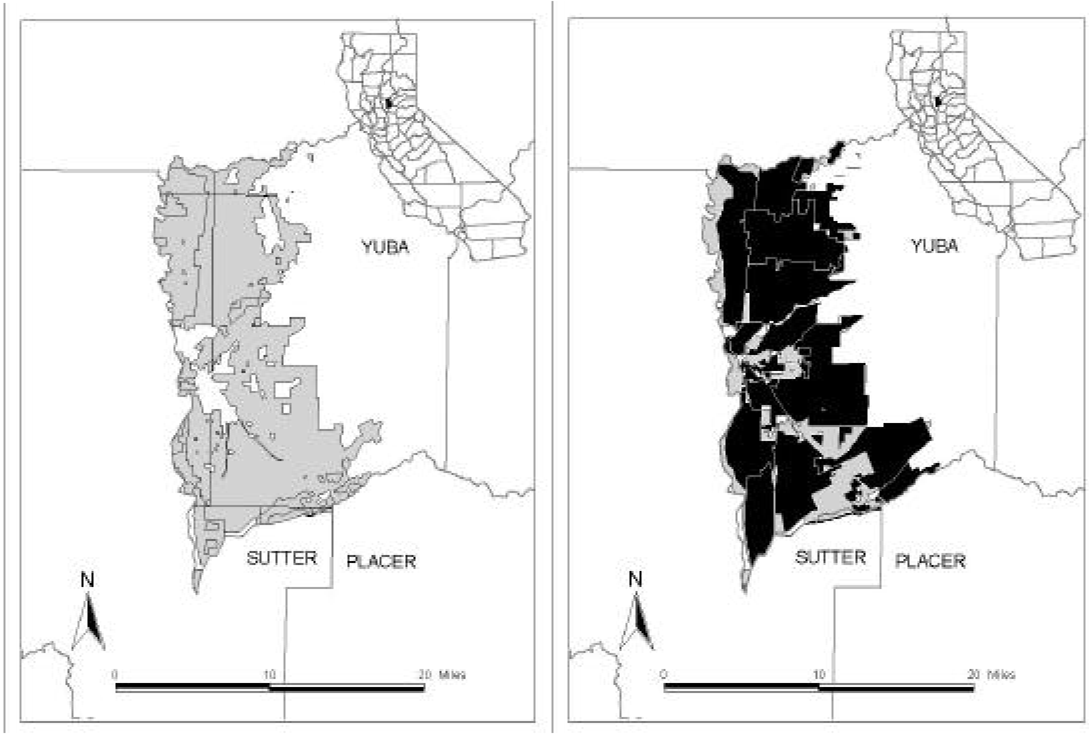


Figure A.12: DAU 170, Honcut Valley, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



(A) (B)

Figure A.13: DAU 171, Yuba, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



(A) (B)

Figure A.14: DAU 172, Placer, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

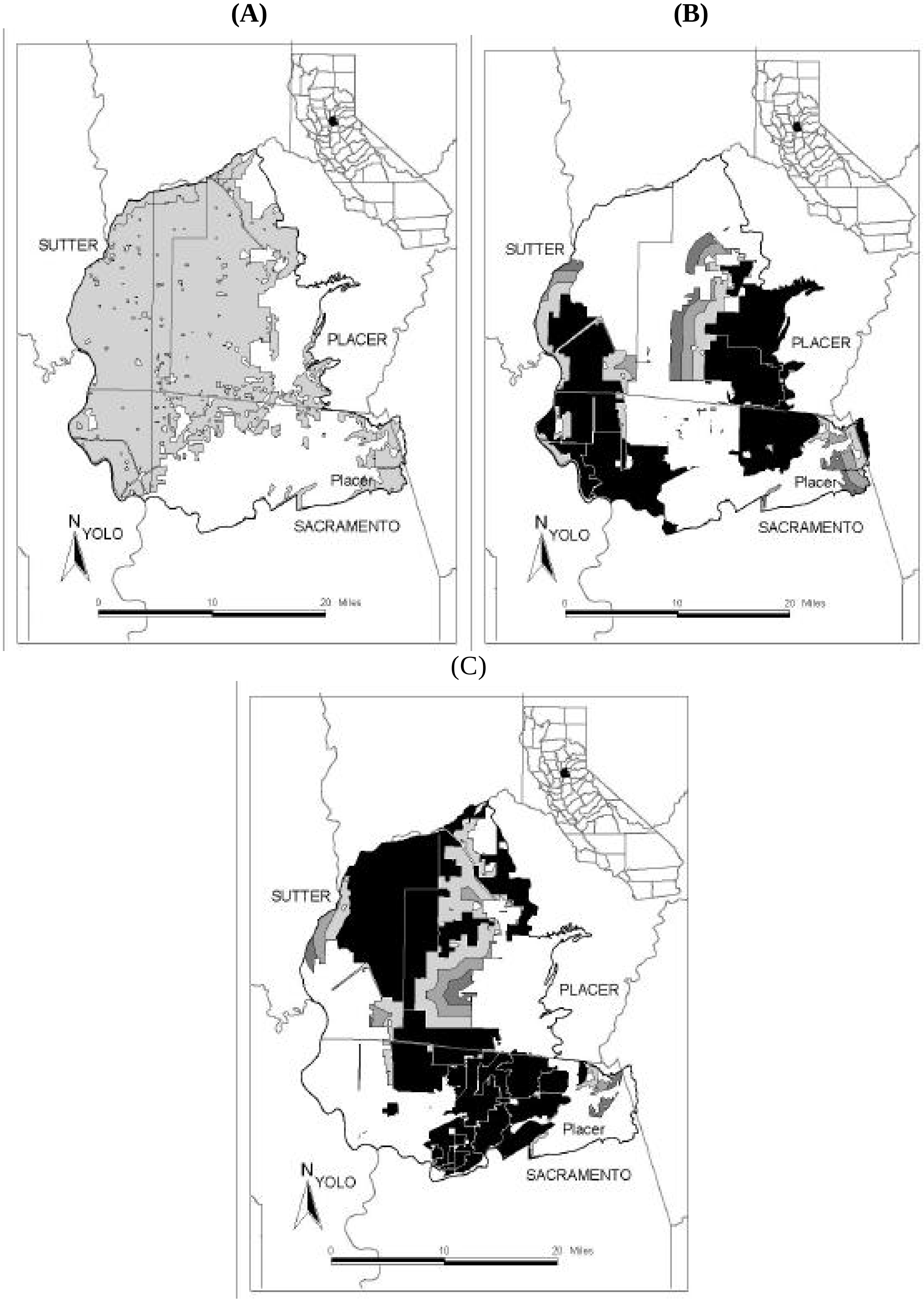
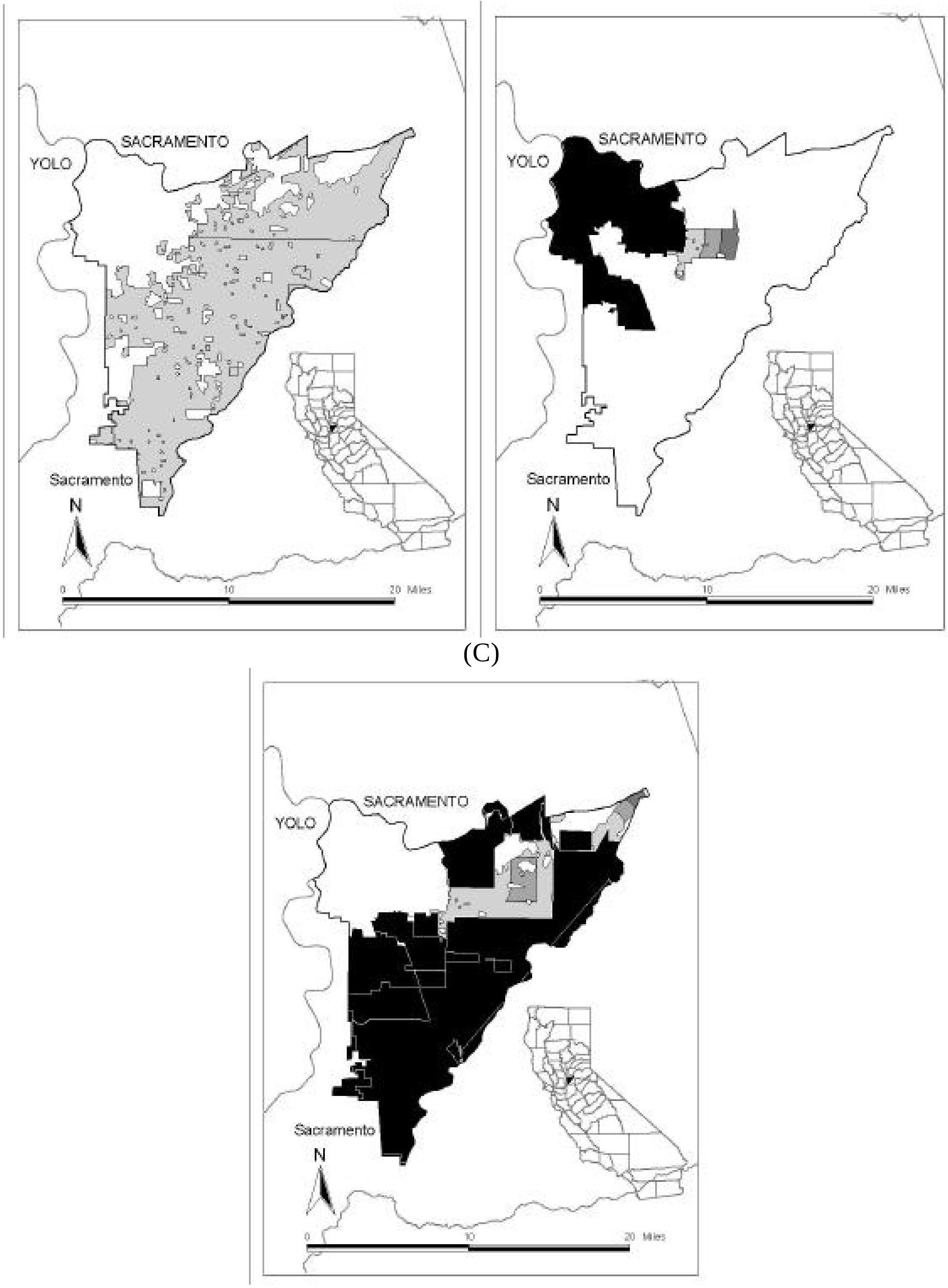


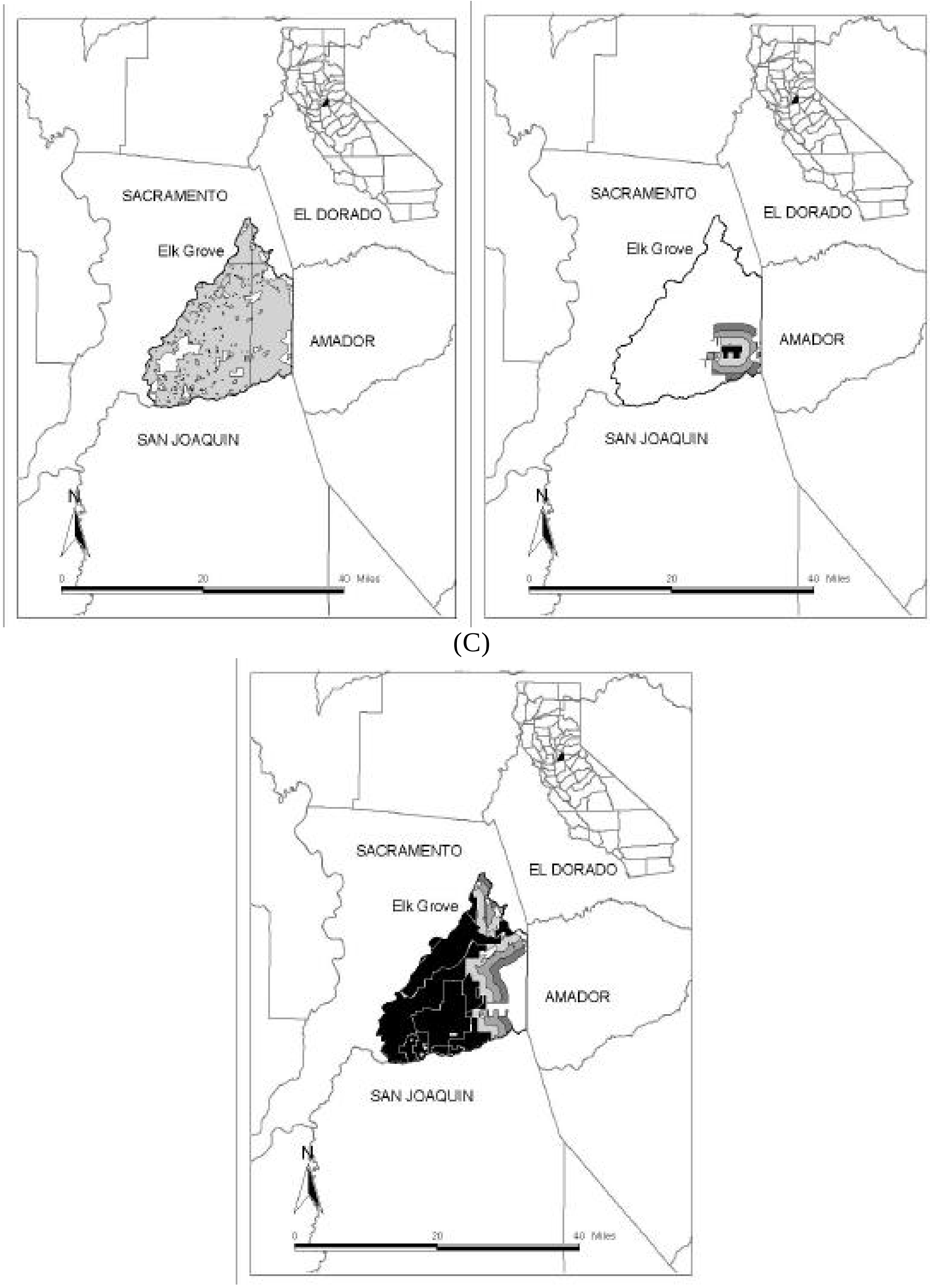
Figure A.15: DAU 173, Sacramento, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A) **(B)**

(C)

Figure A.16: DAU 181, Elk Grove, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A) **(B)**

(C)

Figure A.17: DAU 181, Ione-Jenny Lind, Water Districts Receiving Water from Private Water Supplies (■) that Cover the Entire Detailed Analysis Unit

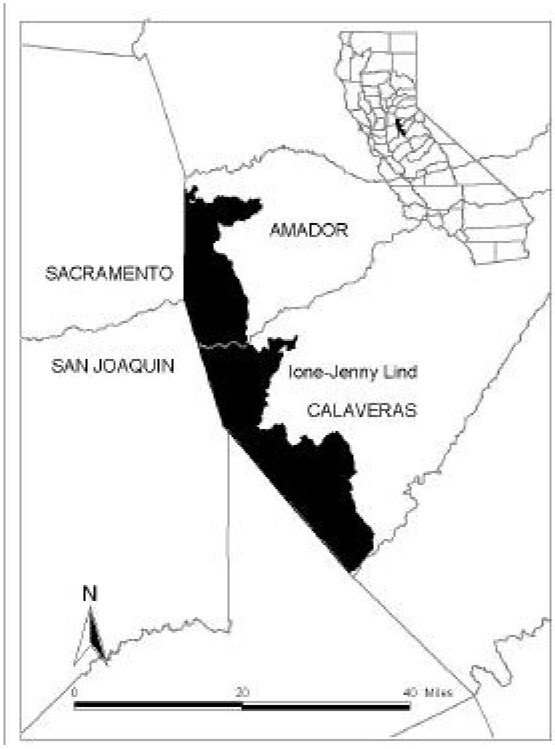


Figure A.18: DAU 182, Lodi, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

(A) **(B)**

(C)

Figure A.19: DAU 184, Bachelor Valley, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)

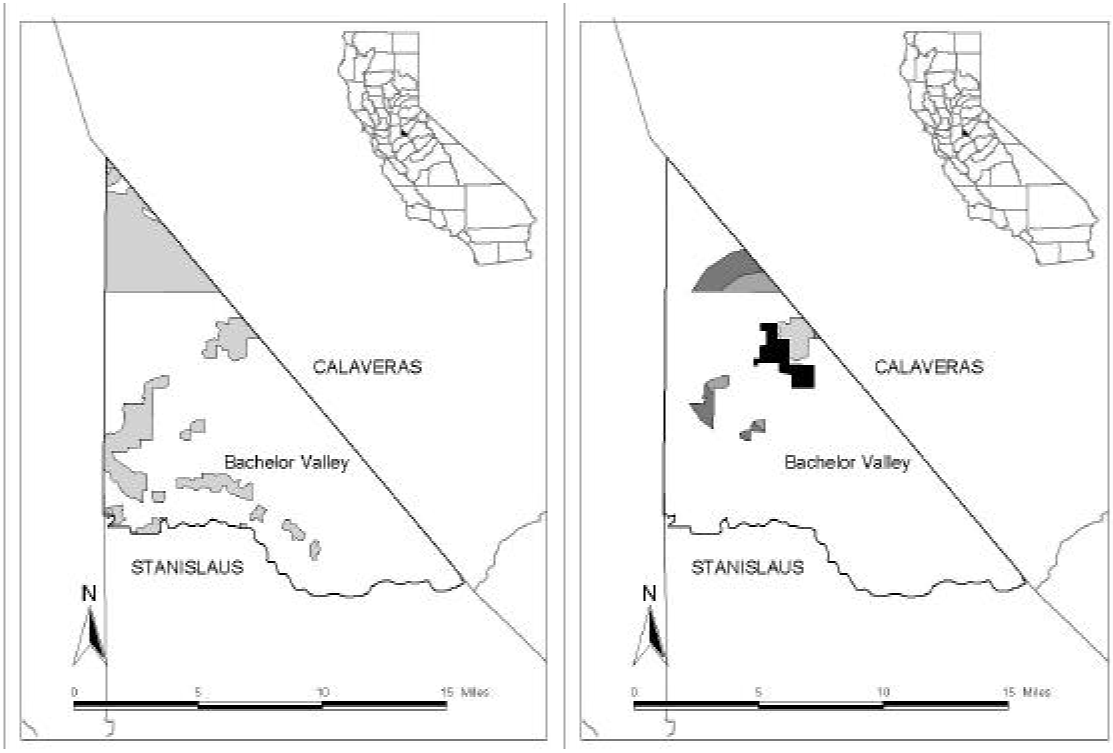
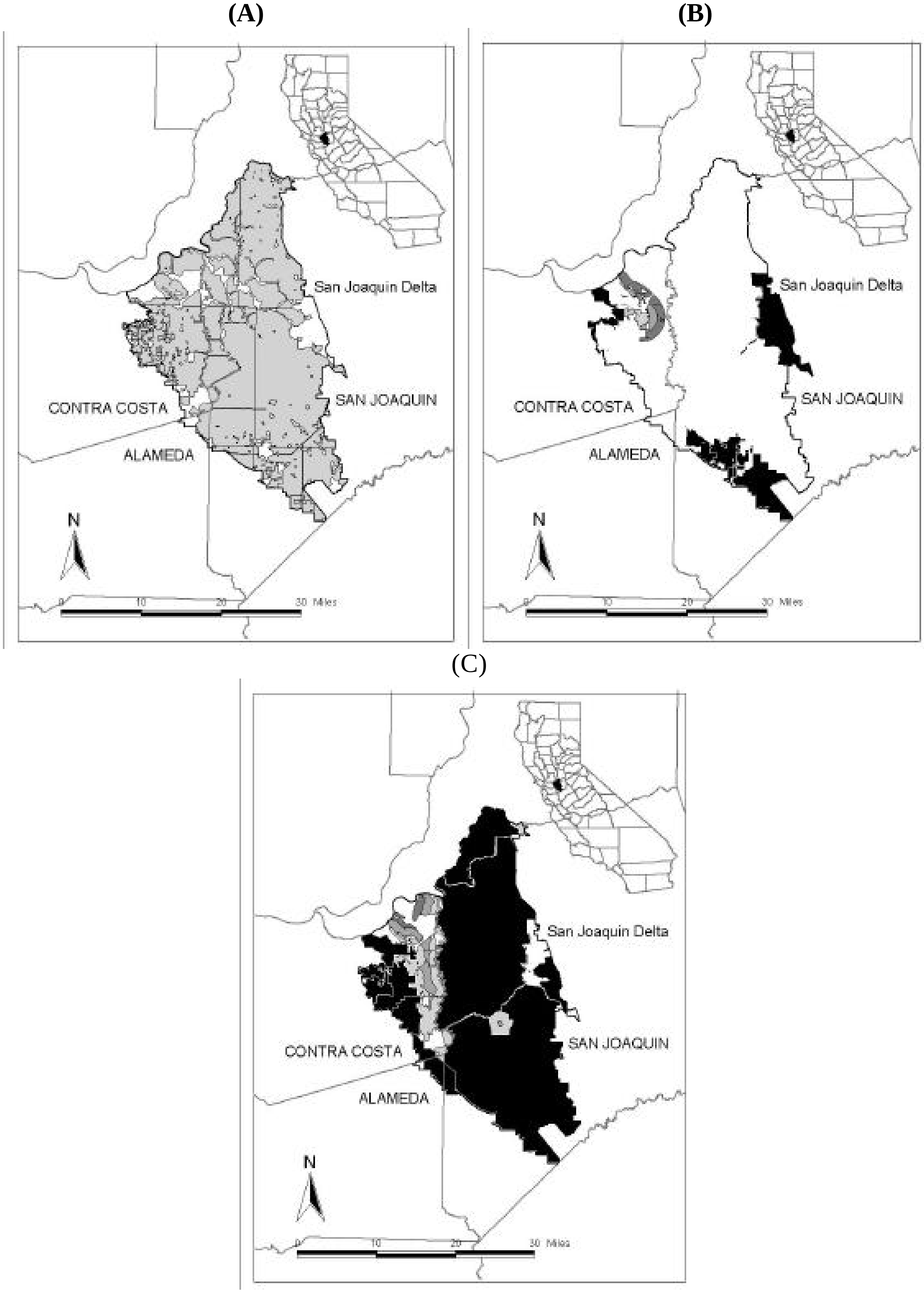

(A) (B)

Figure A.20: DAU 185, San Joaquin Delta, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)


(A)

(B)

(C)

Figure A.21: DAU 186, Sacramento Delta, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

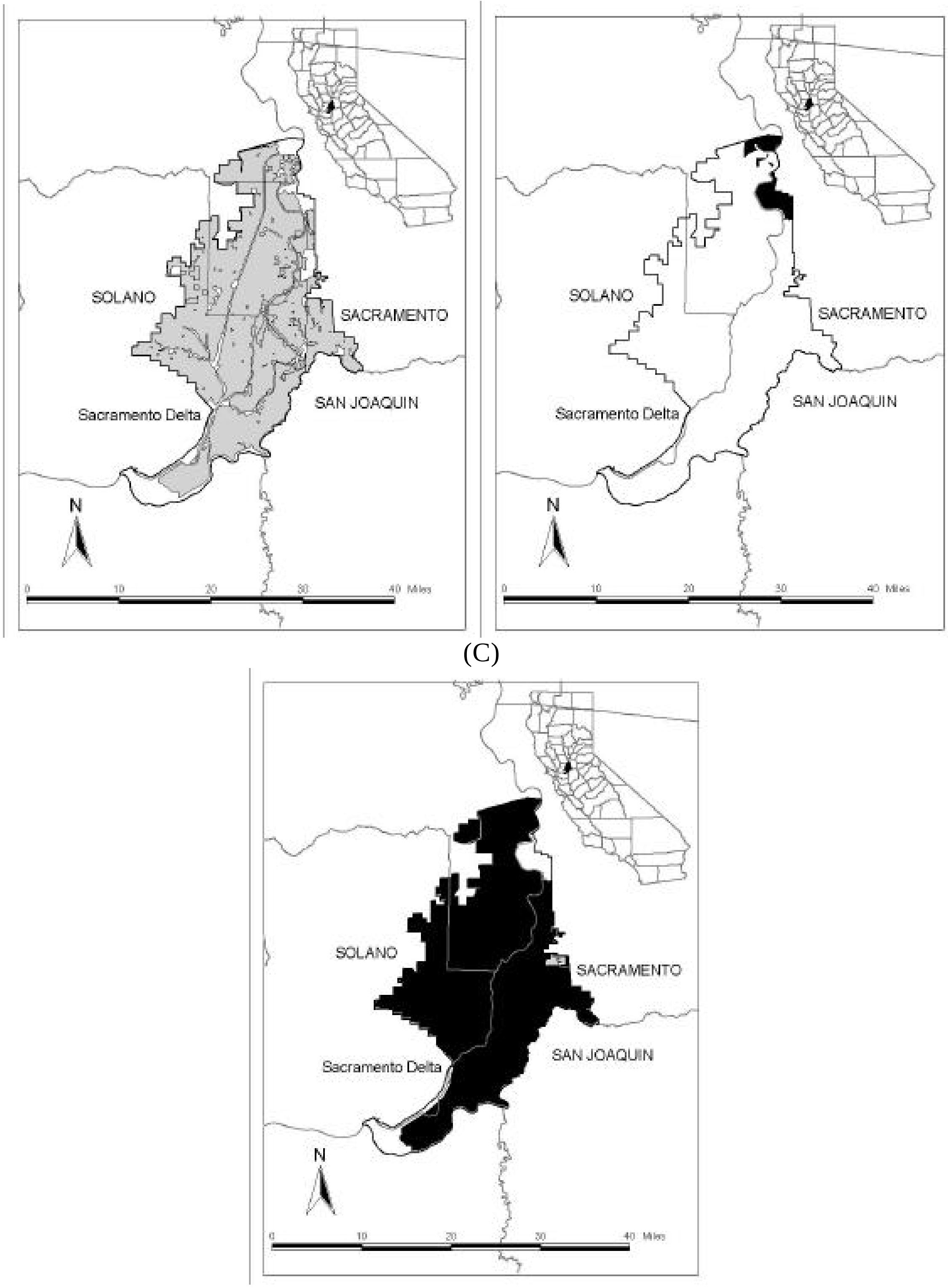
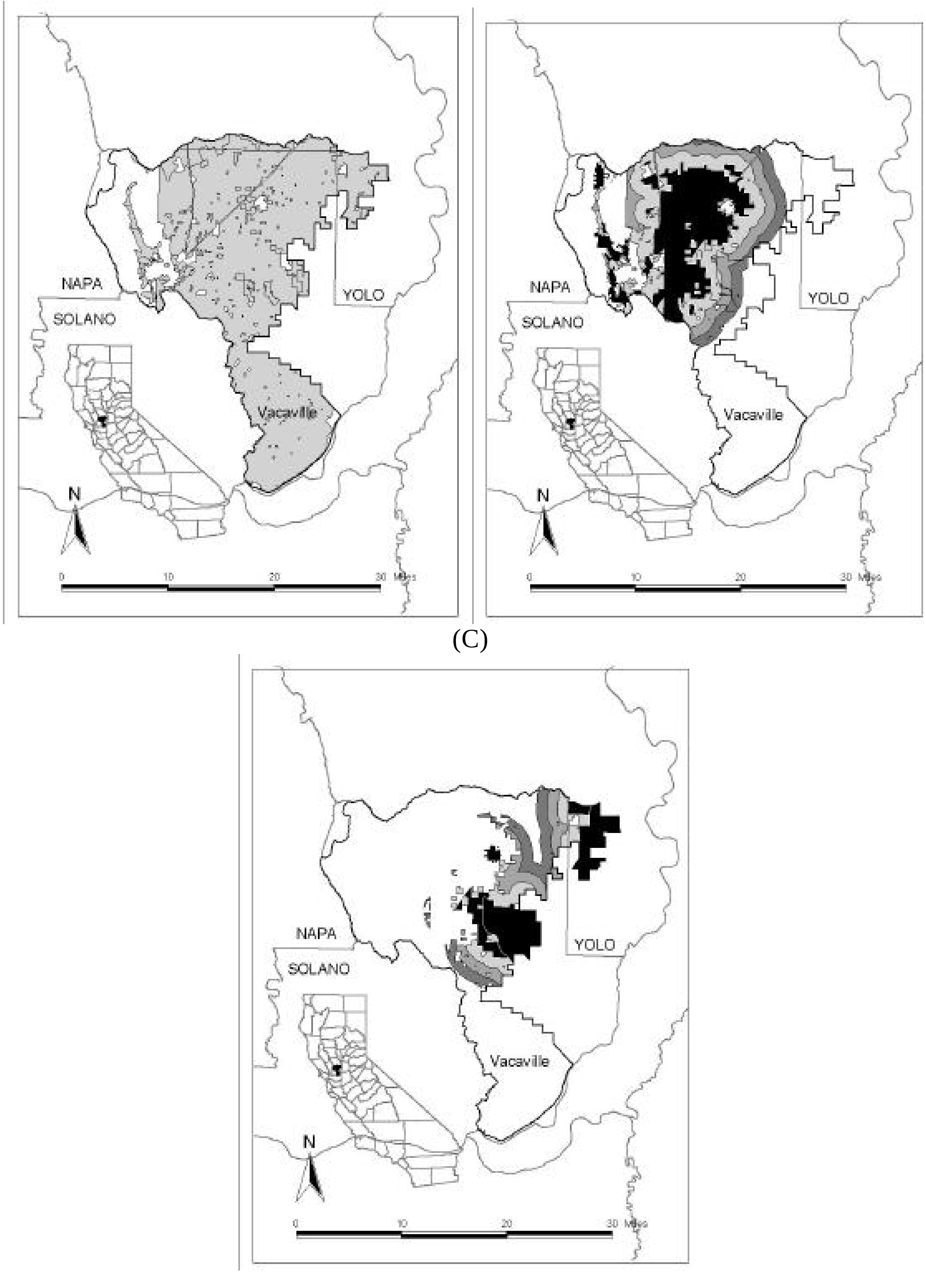

(A)
(B)
(C)

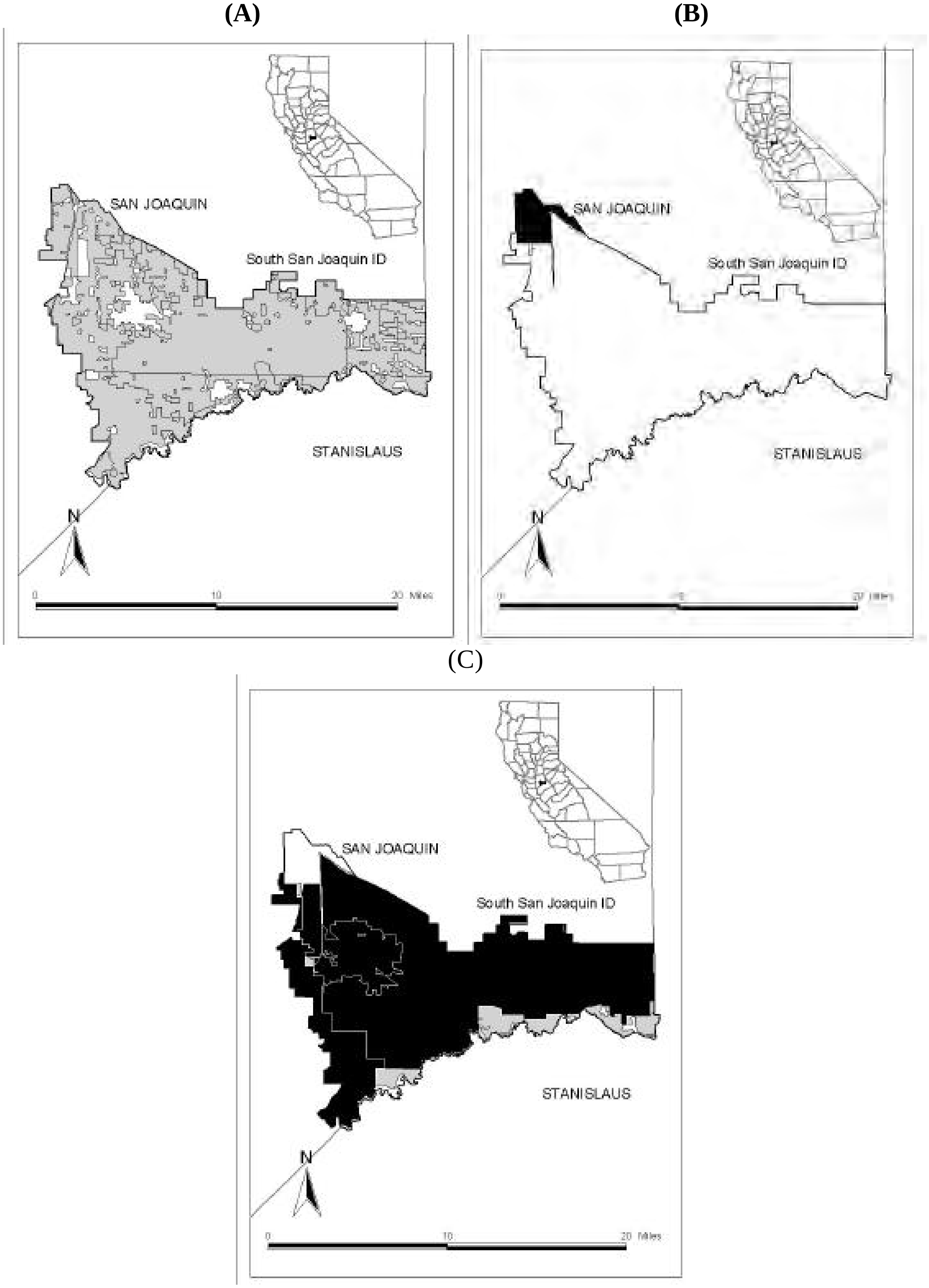
Figure A.22: DAU 191, Vacaville, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A) **(B)**

(C)

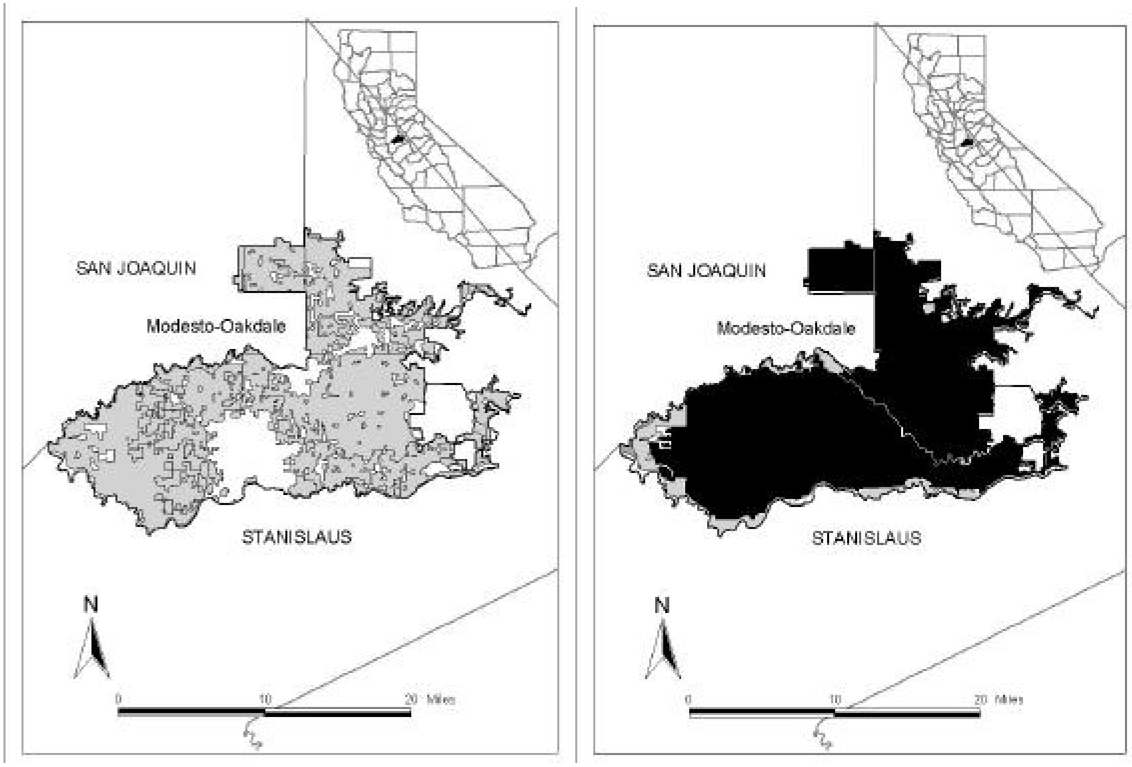
Figure A.23: DAU 205, South San Joaquin ID, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A) **(B)**

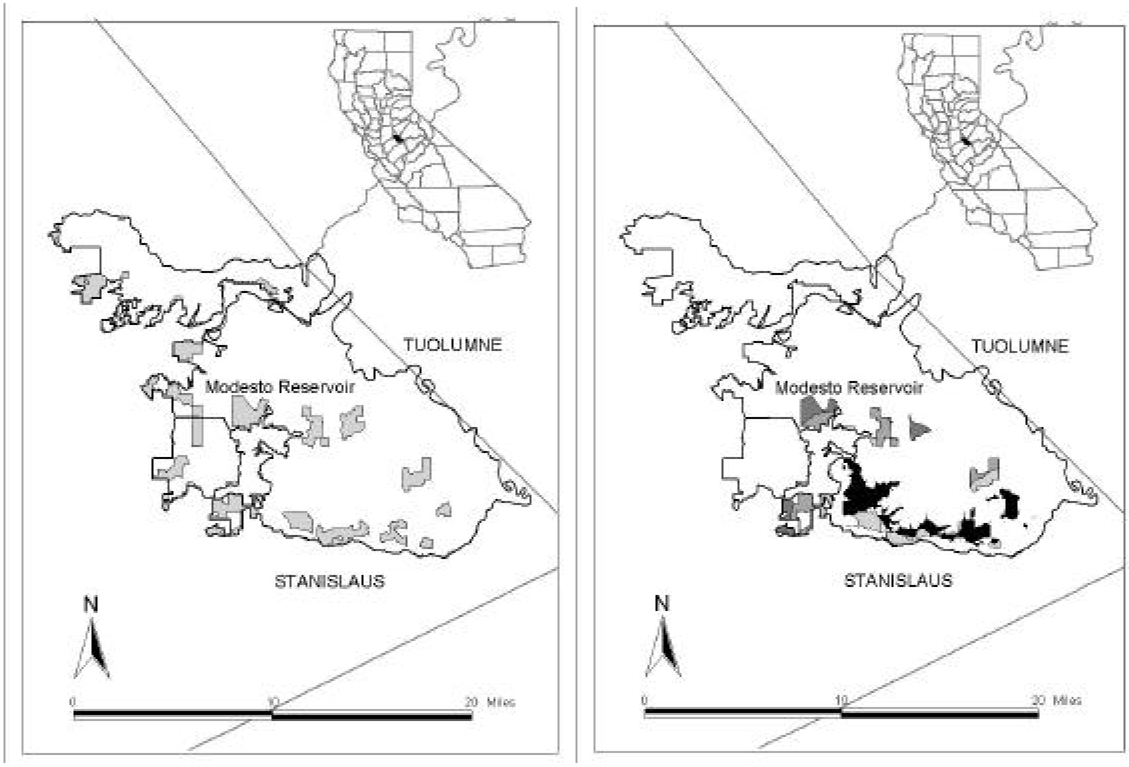
(C)

Figure A.24: DAU 206, Modesto-Oakdale, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



(A) (B)

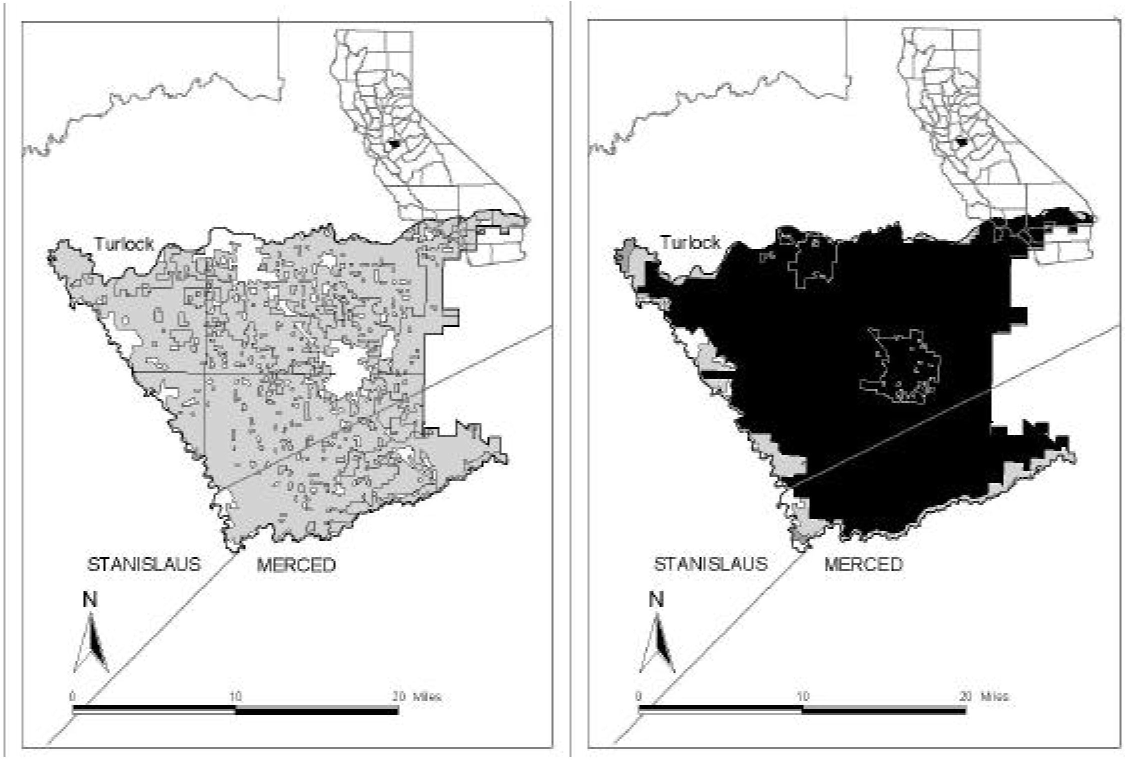
Figure A.25: DAU 207, Modesto Reservoir, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



(A)

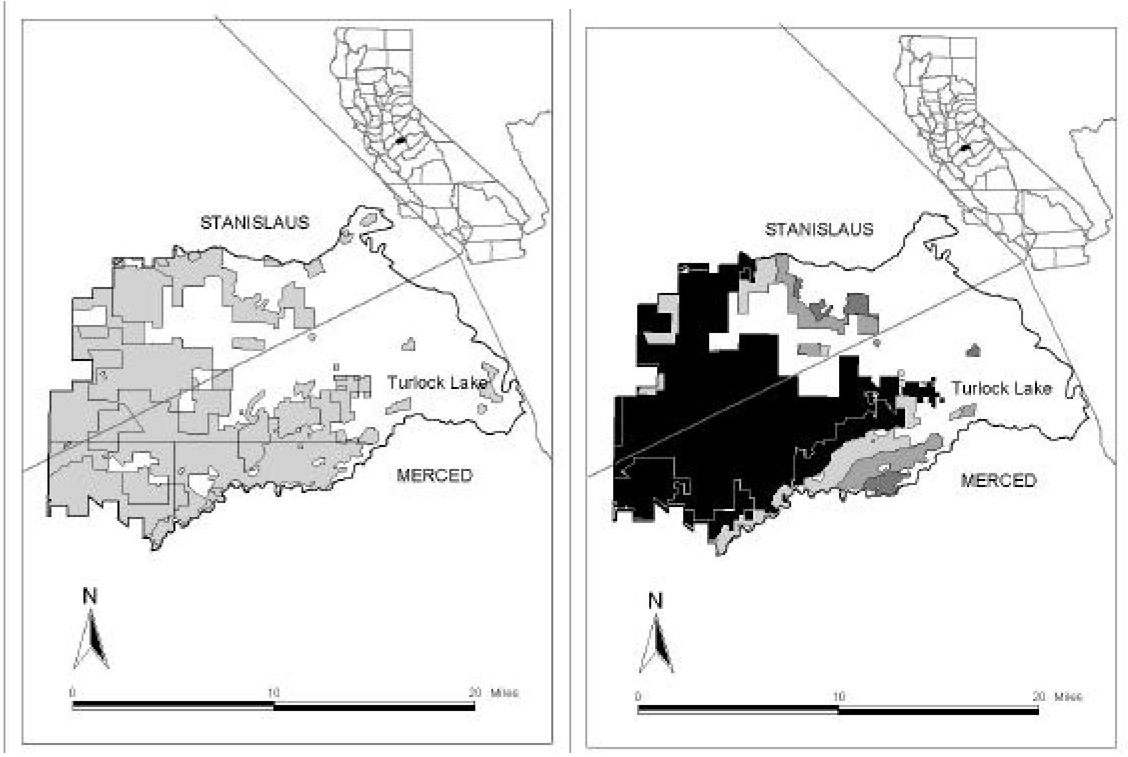
(B)

Figure A.26: DAU 208, Turlock, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



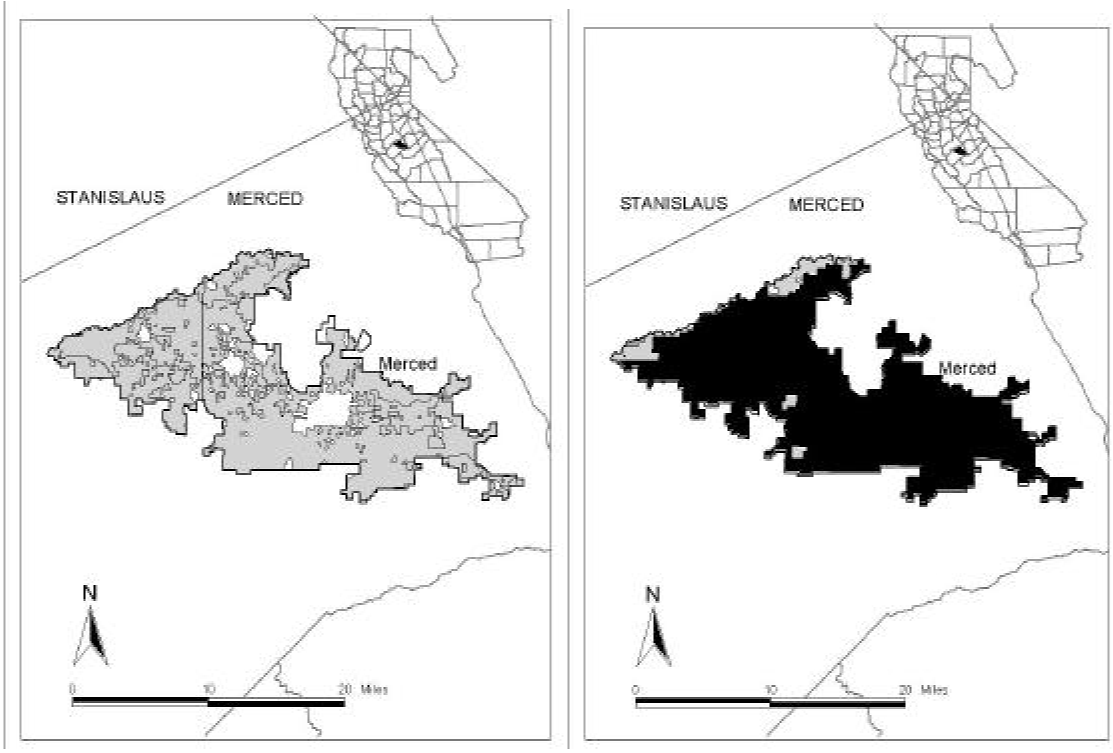
(A) (B)

Figure A.27: DAU 209, Turlock Lake, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



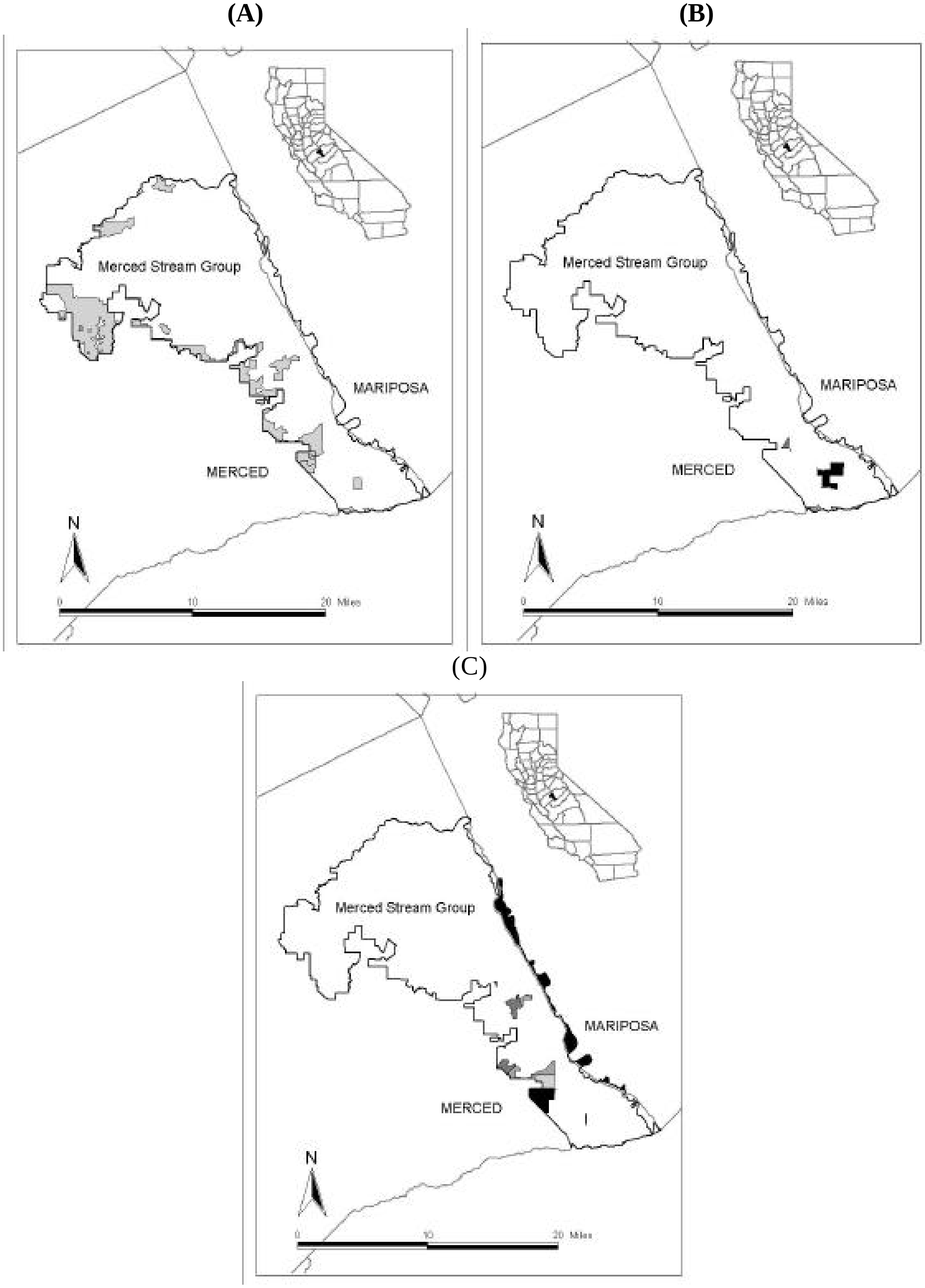
(A) (B)

Figure A.28: DAU 210, Merced, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



(A) (B)

Figure A.29: DAU 211, Merced Stream Group, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

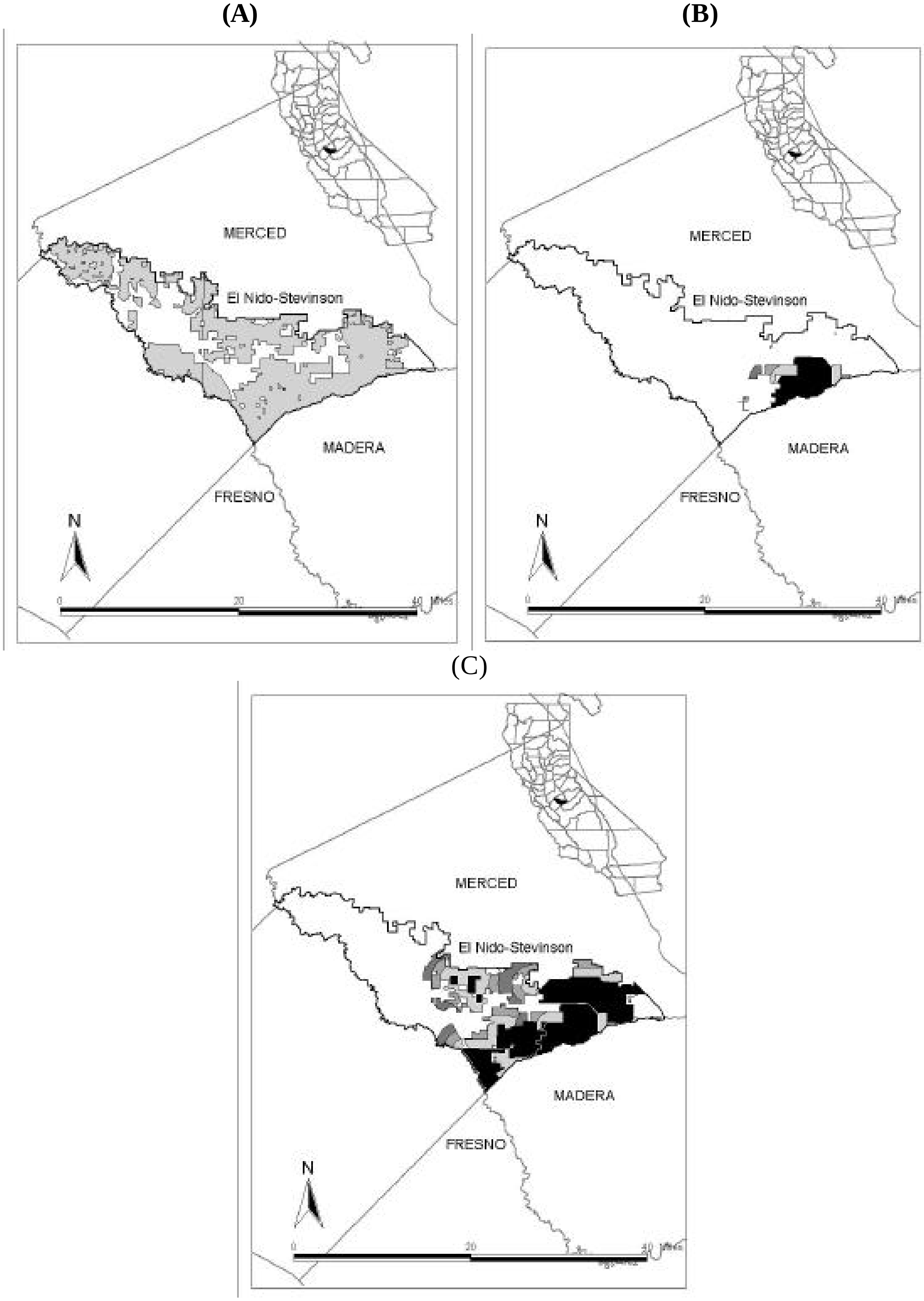


(A)

(B)

(C)

Figure A.30: DAU 212, El Nido-Stevinson, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒), and 3 (▓) Miles of Private Water Districts (C)



(A)

(B)

(C)

Figure A.31: DAU 213, Madera-Chowchilla, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒), and 3 (▓) Miles of Private Water Districts (C)

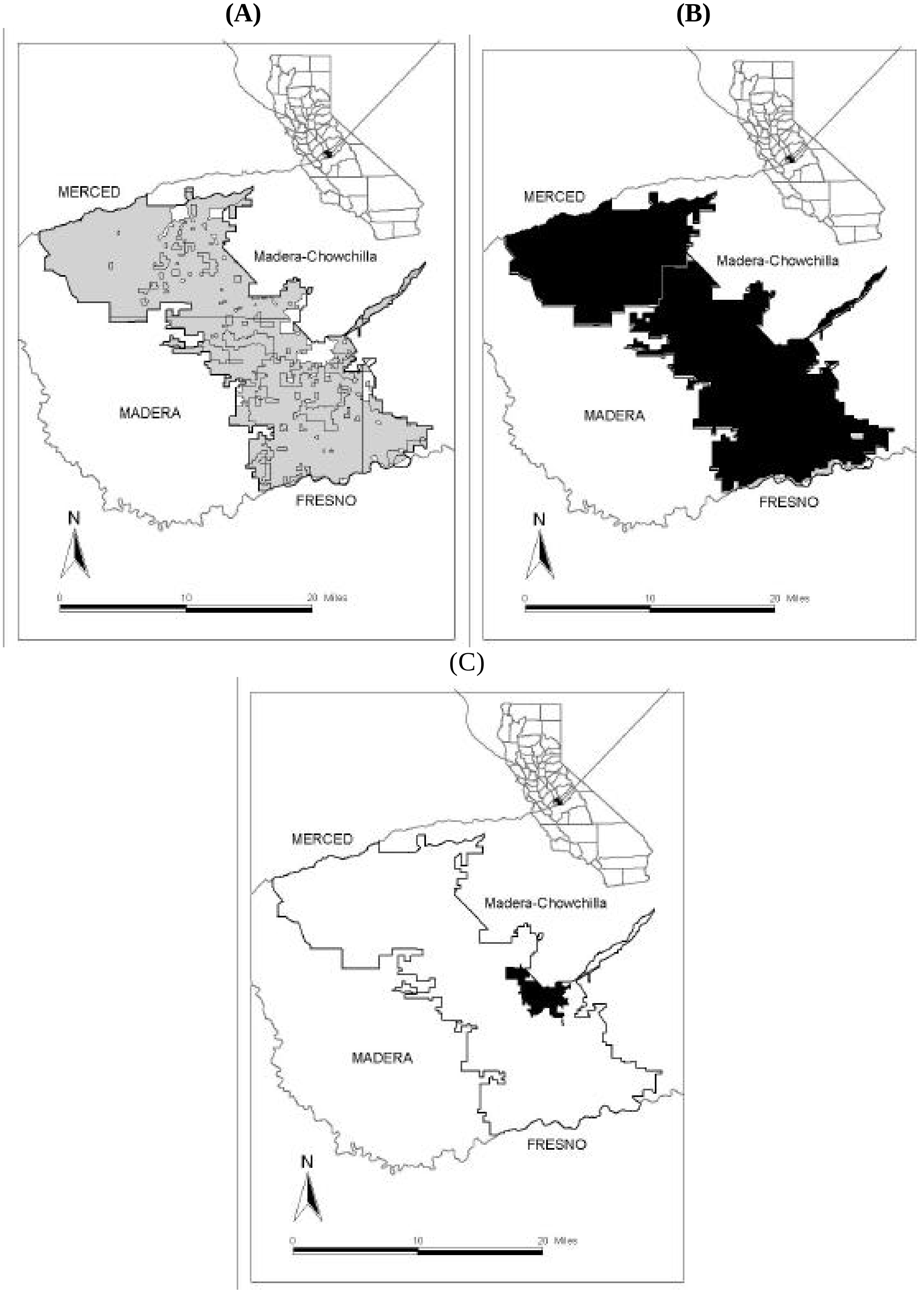
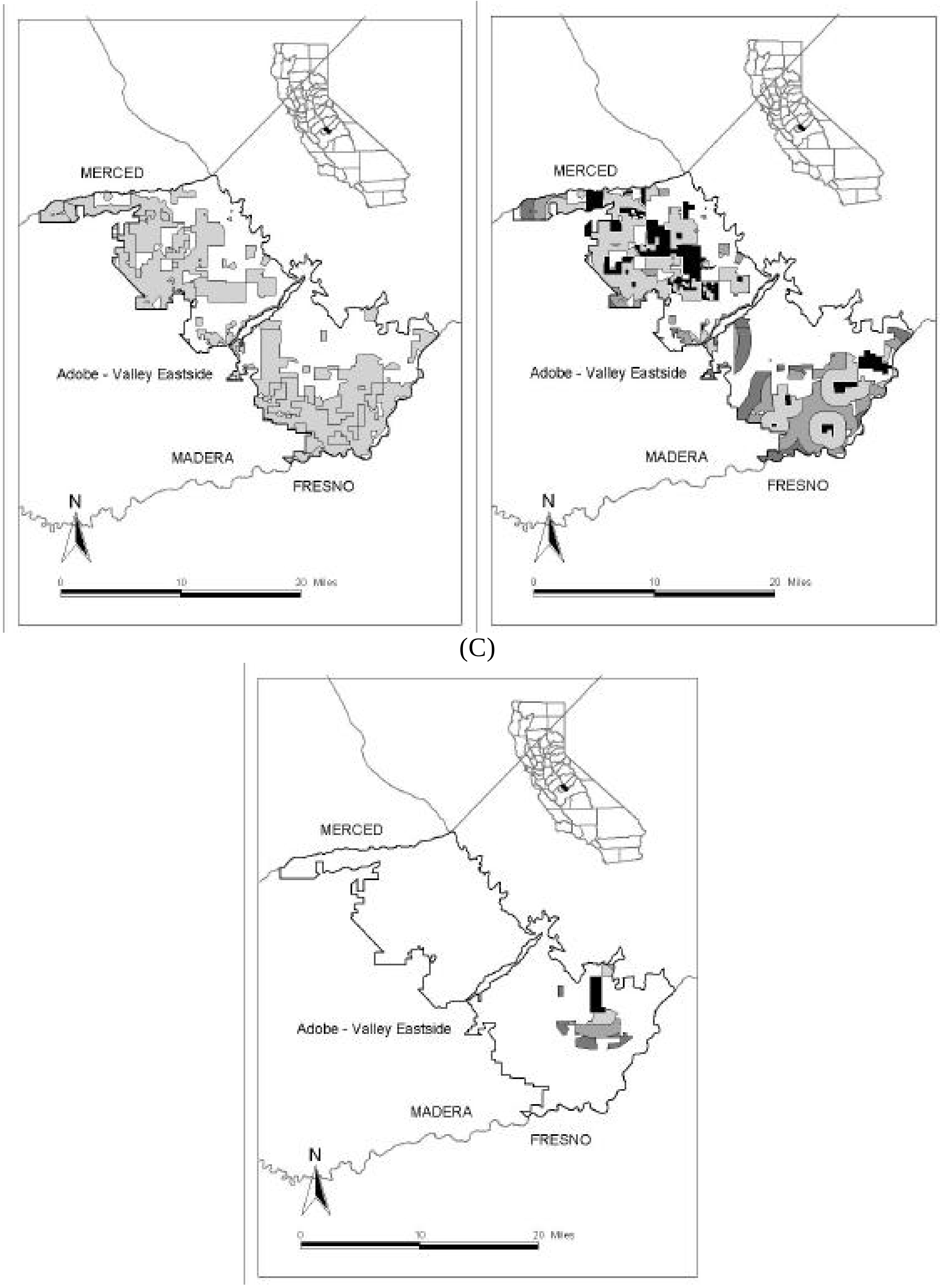


Figure A.32: DAU 214, Adobe-Valley Eastside, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A)

(B)

(C)

Figure A.33: DAU 215, Gravelly Ford, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

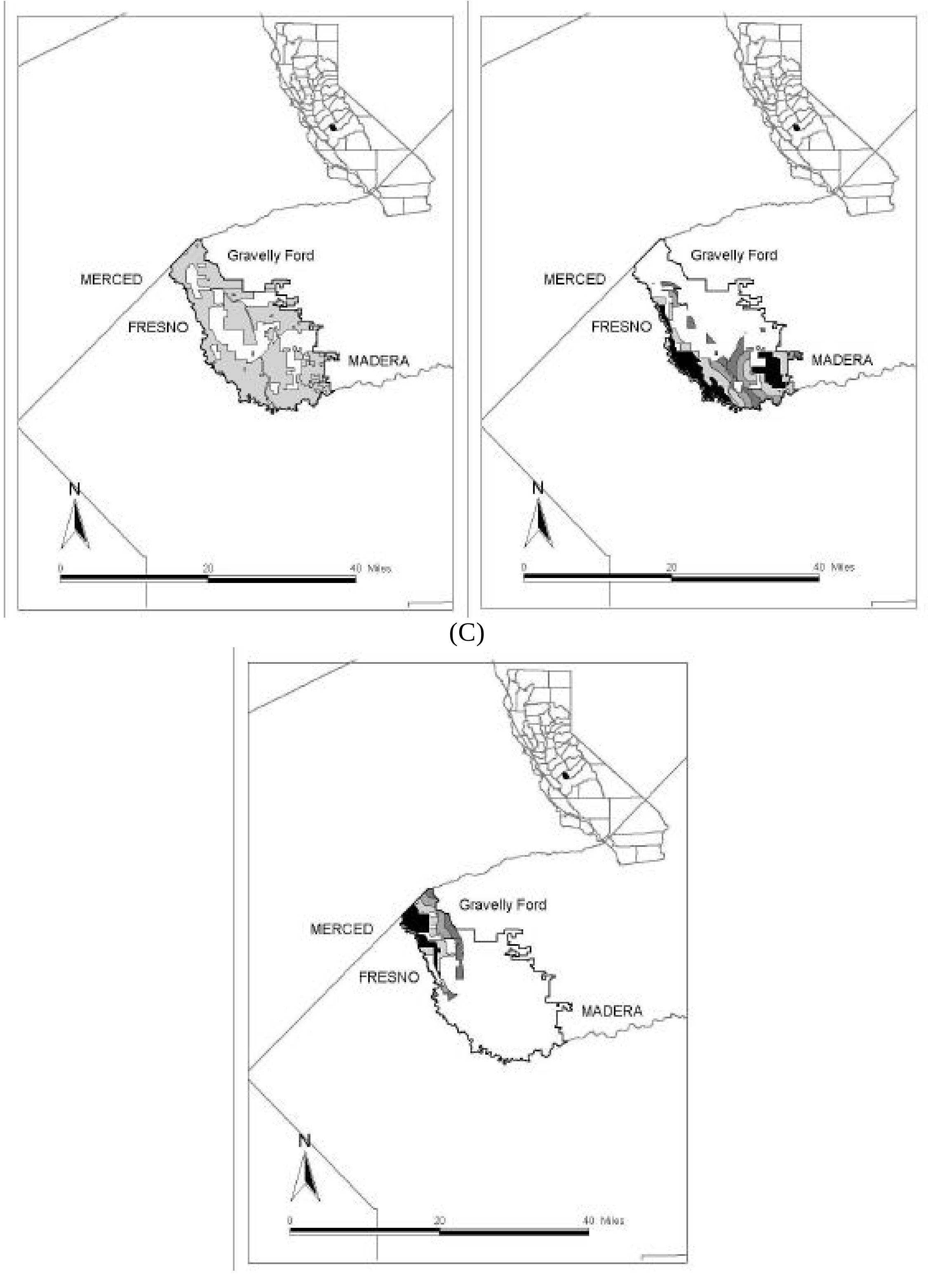

(A)
(B)
(C)

Figure A.34: DAU 216, West Side, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (C), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (D)

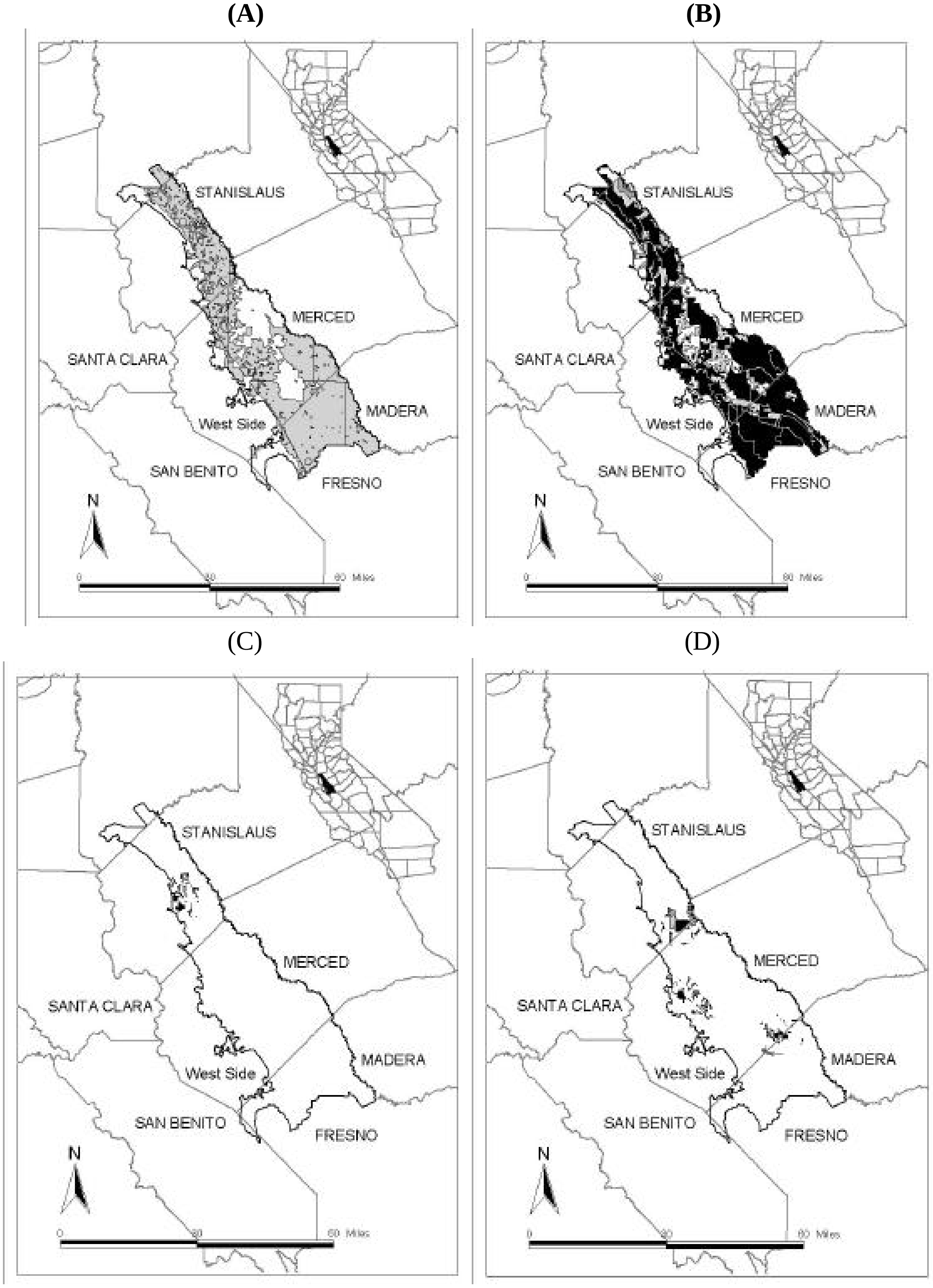
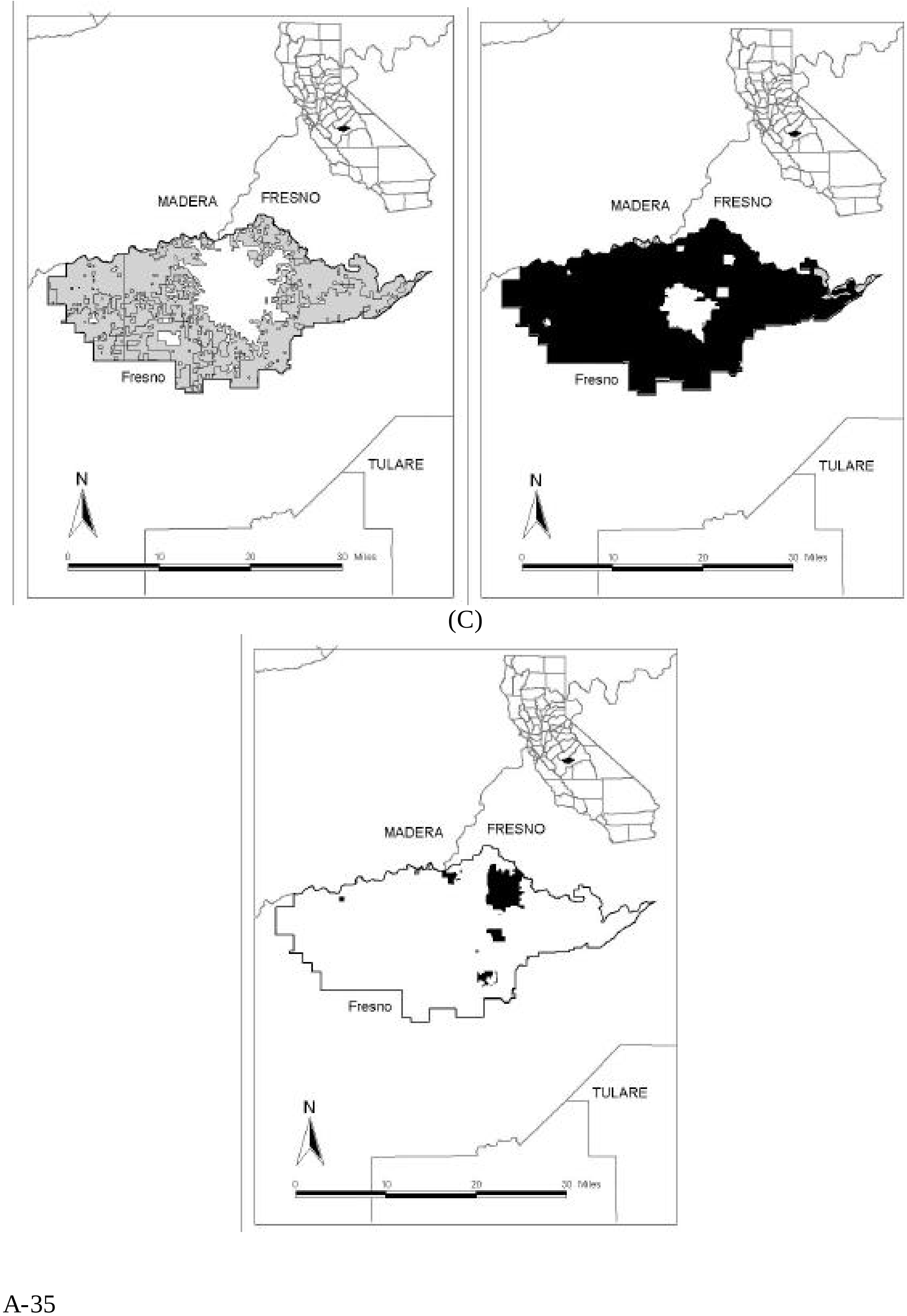

(A) (B) (C) (D)

Figure A.35: DAU 233, Fresno, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A) **(B)**

(C)

Figure A.36: DAU 234, Academy, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B)

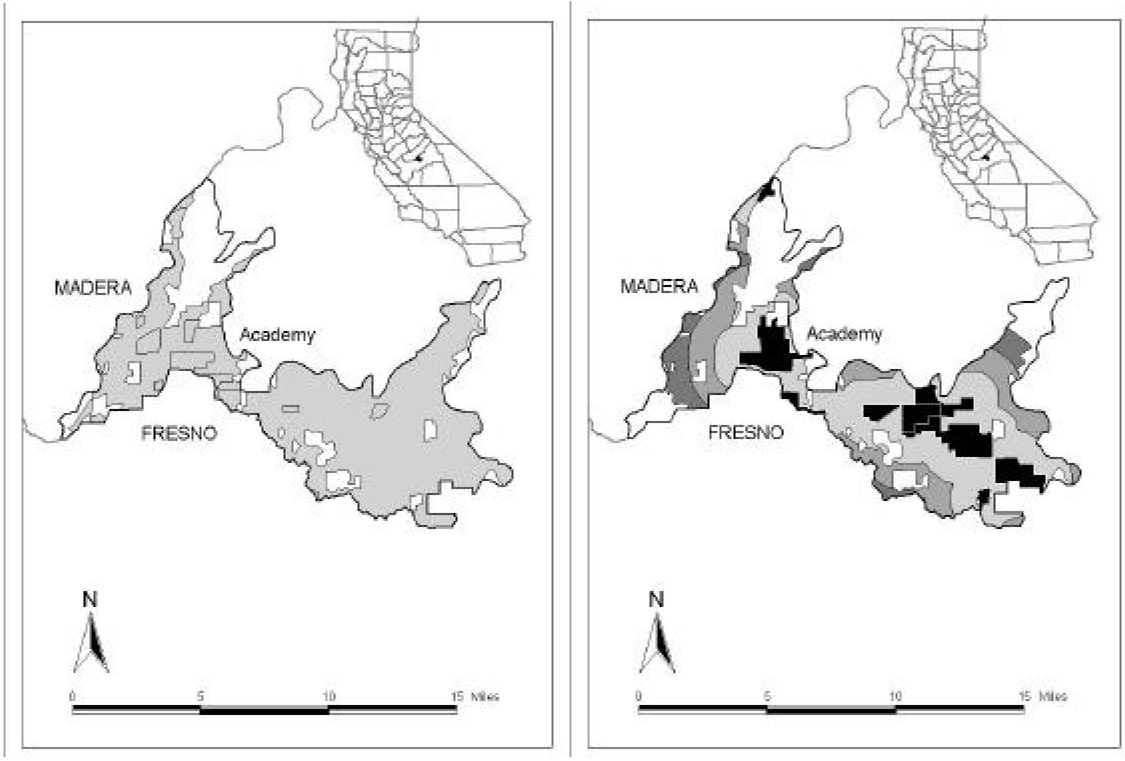

(A) (B)

Figure A.37: DAU 235, Raisin, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

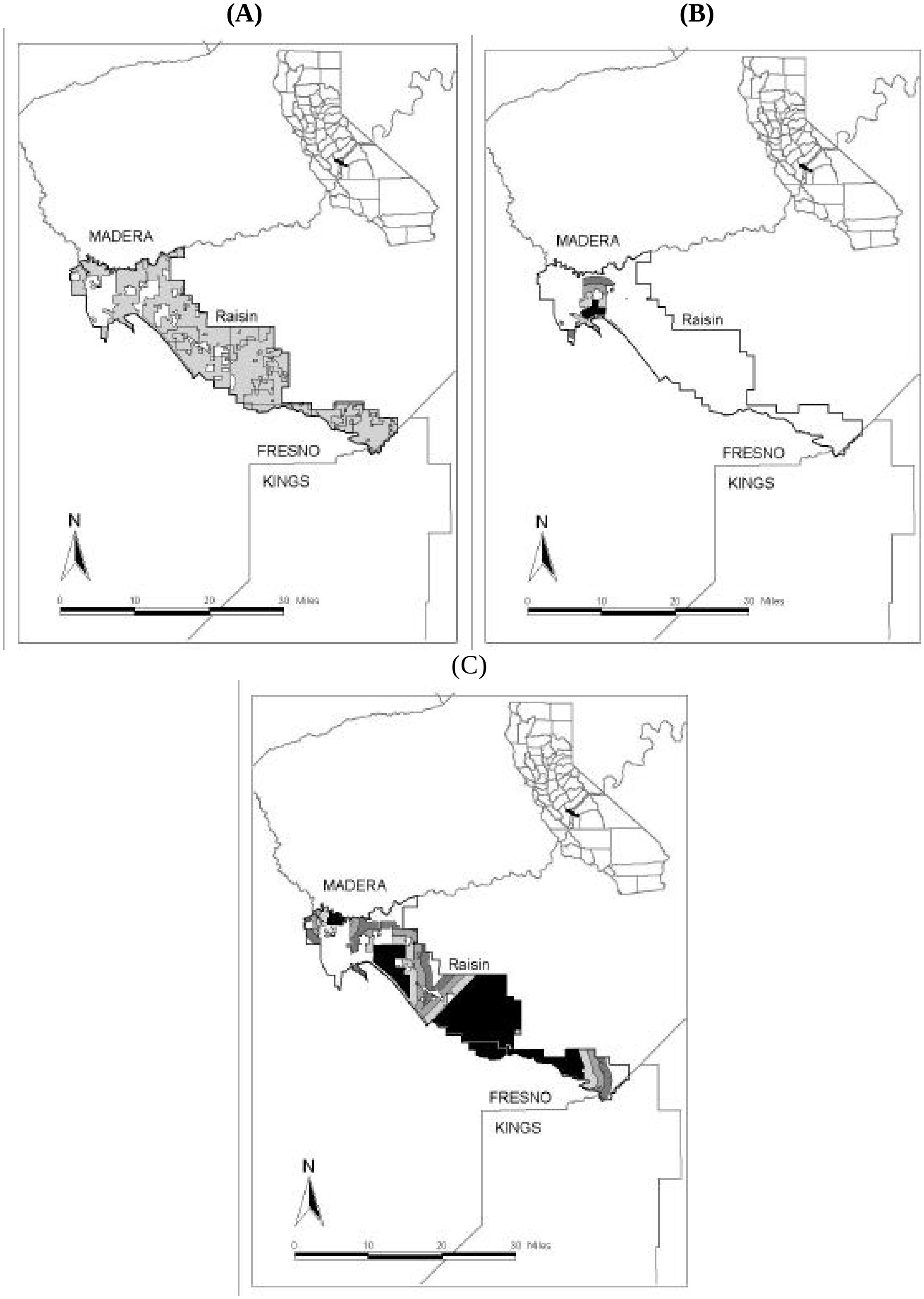
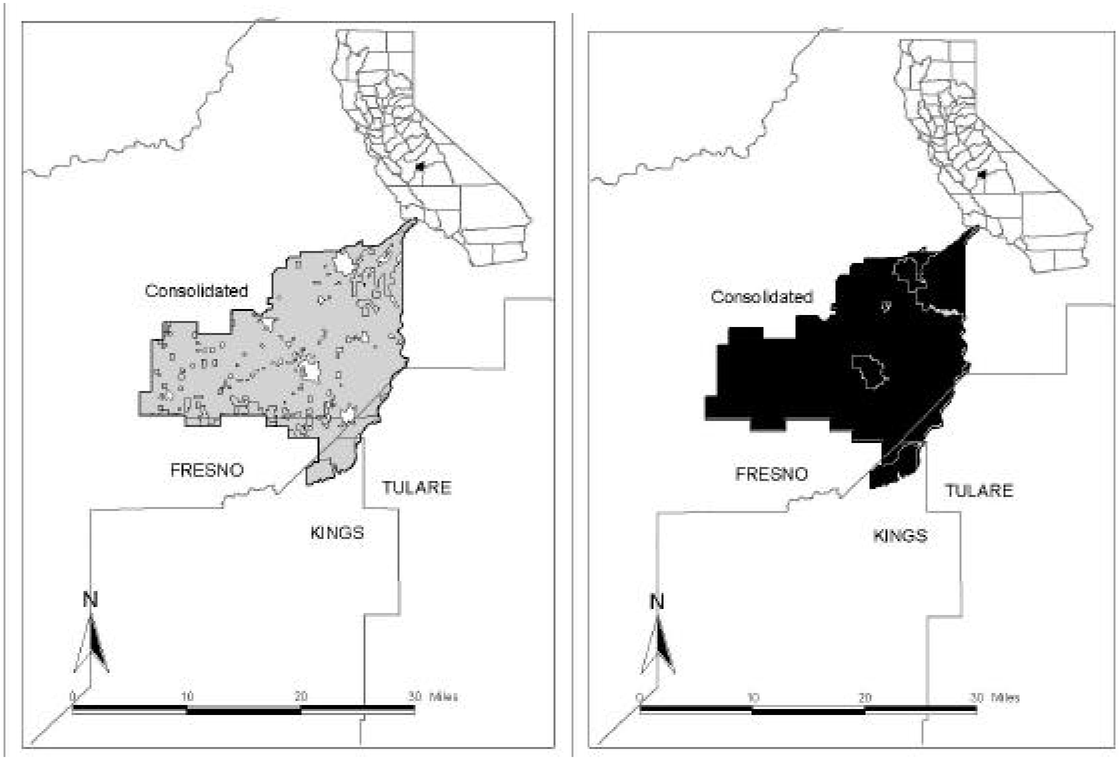


Figure A.38: DAU 236, Consolidated, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



(A)

(B)

Figure A.39: DAU 237, Raisin, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

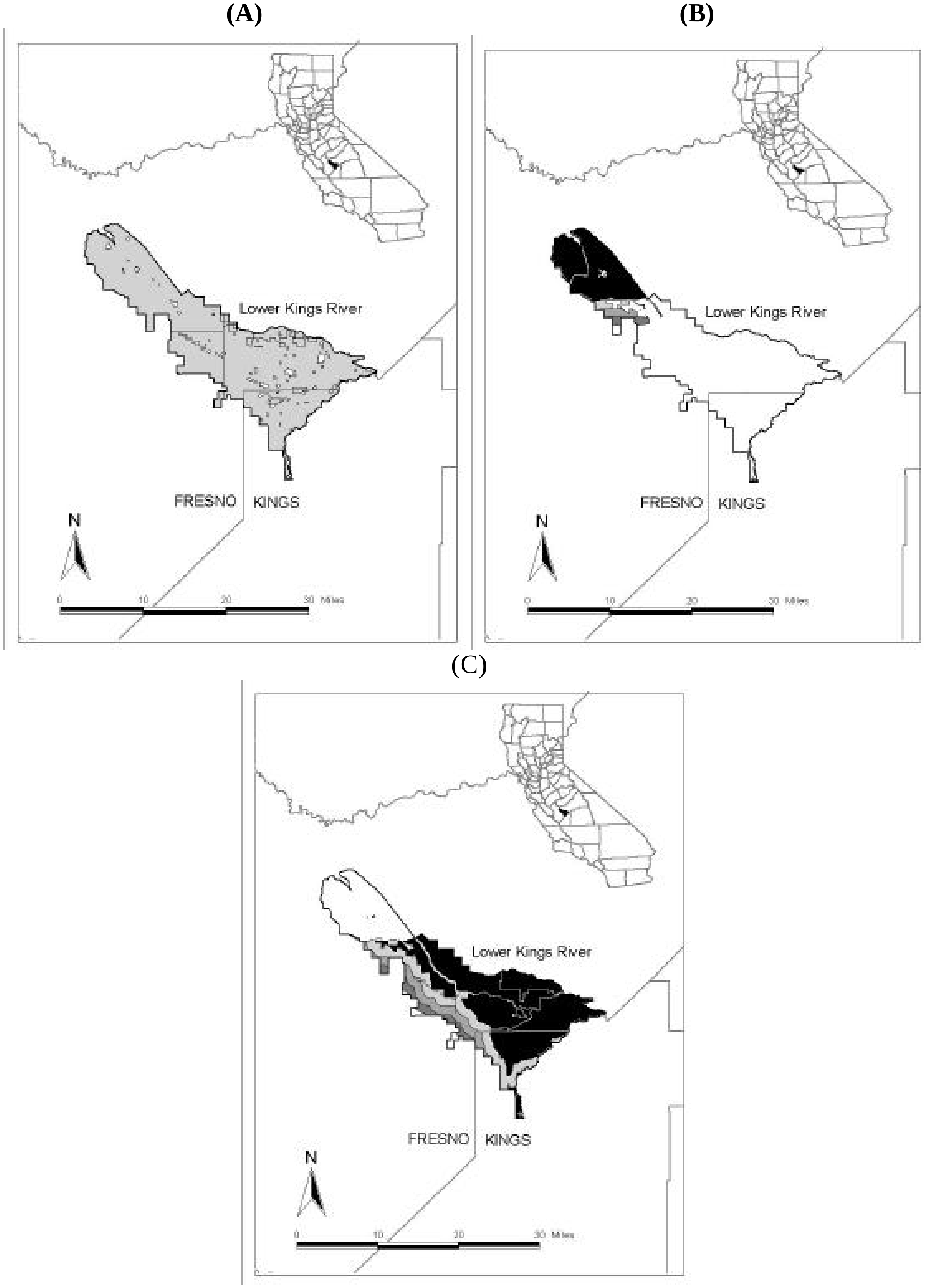
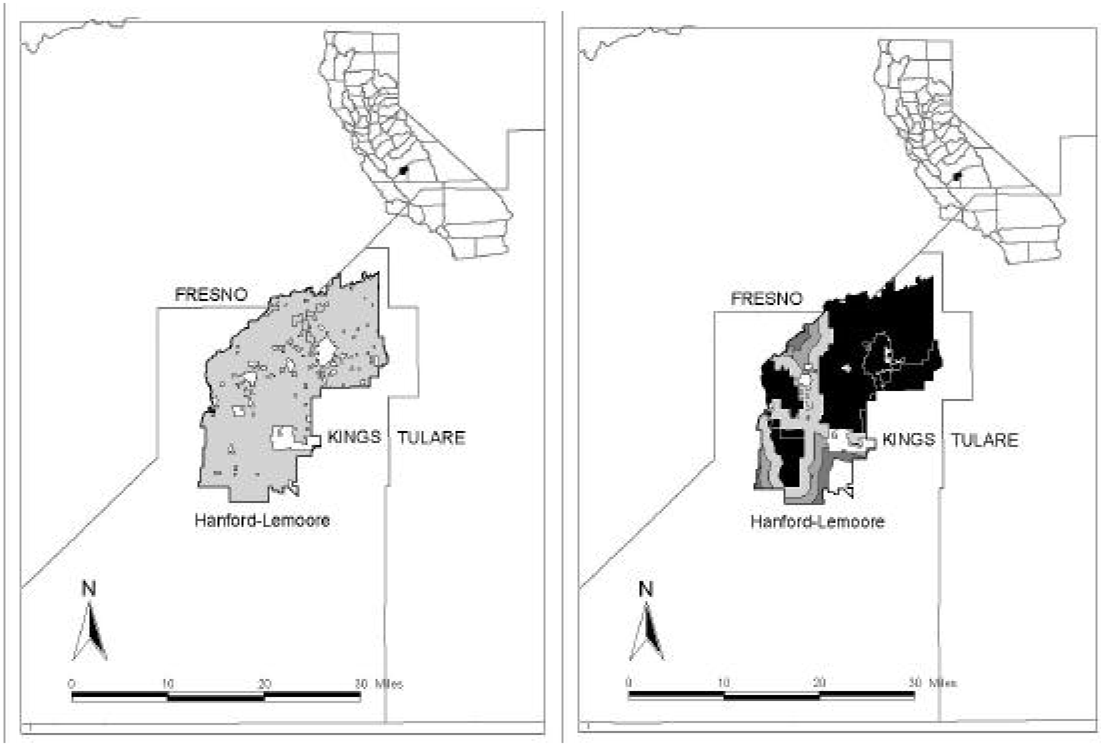


Figure A.40: DAU 238, Hanford-Lemoore, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)



(A) (B)

Figure A.41: DAU 239, Alta, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Private Water Districts (B)

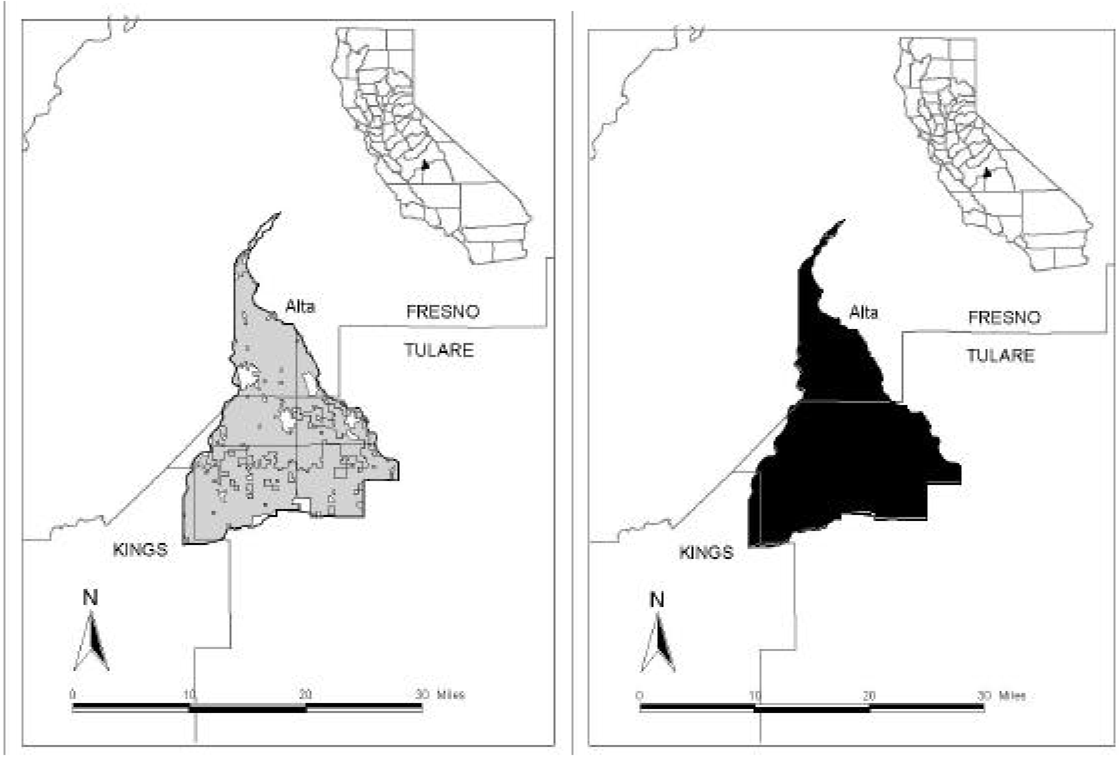

(A)
(B)

Figure A.42: DAU 240, Orange Cove, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B)

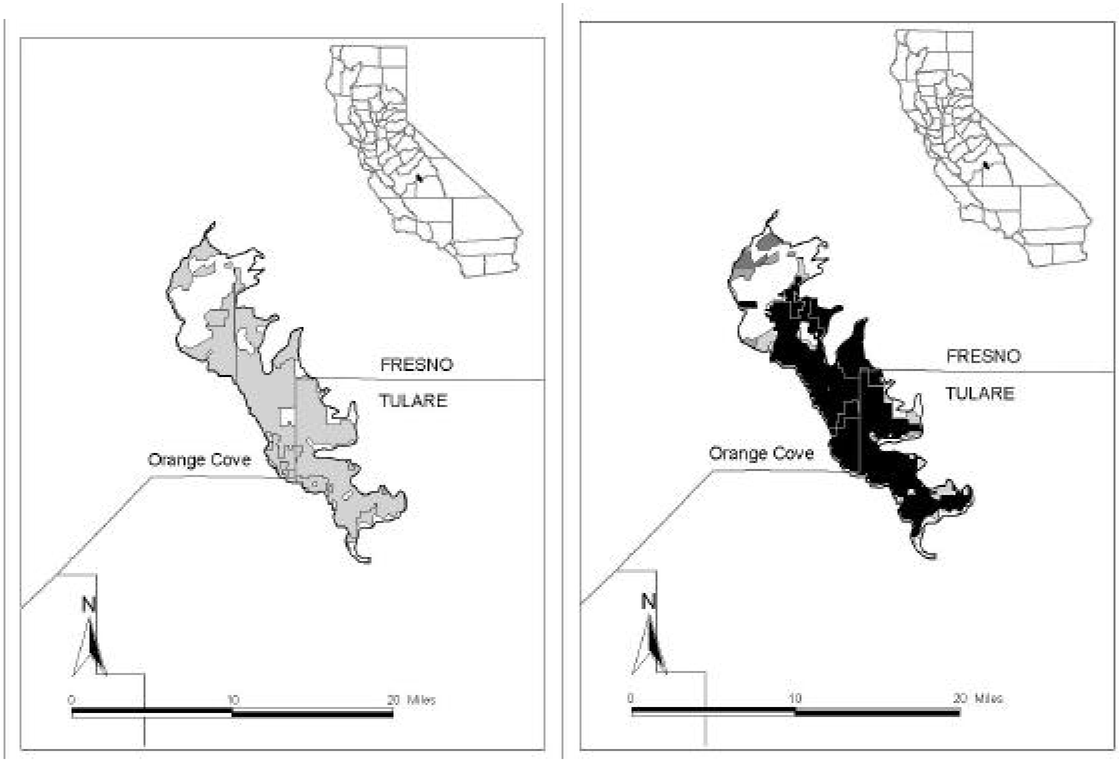
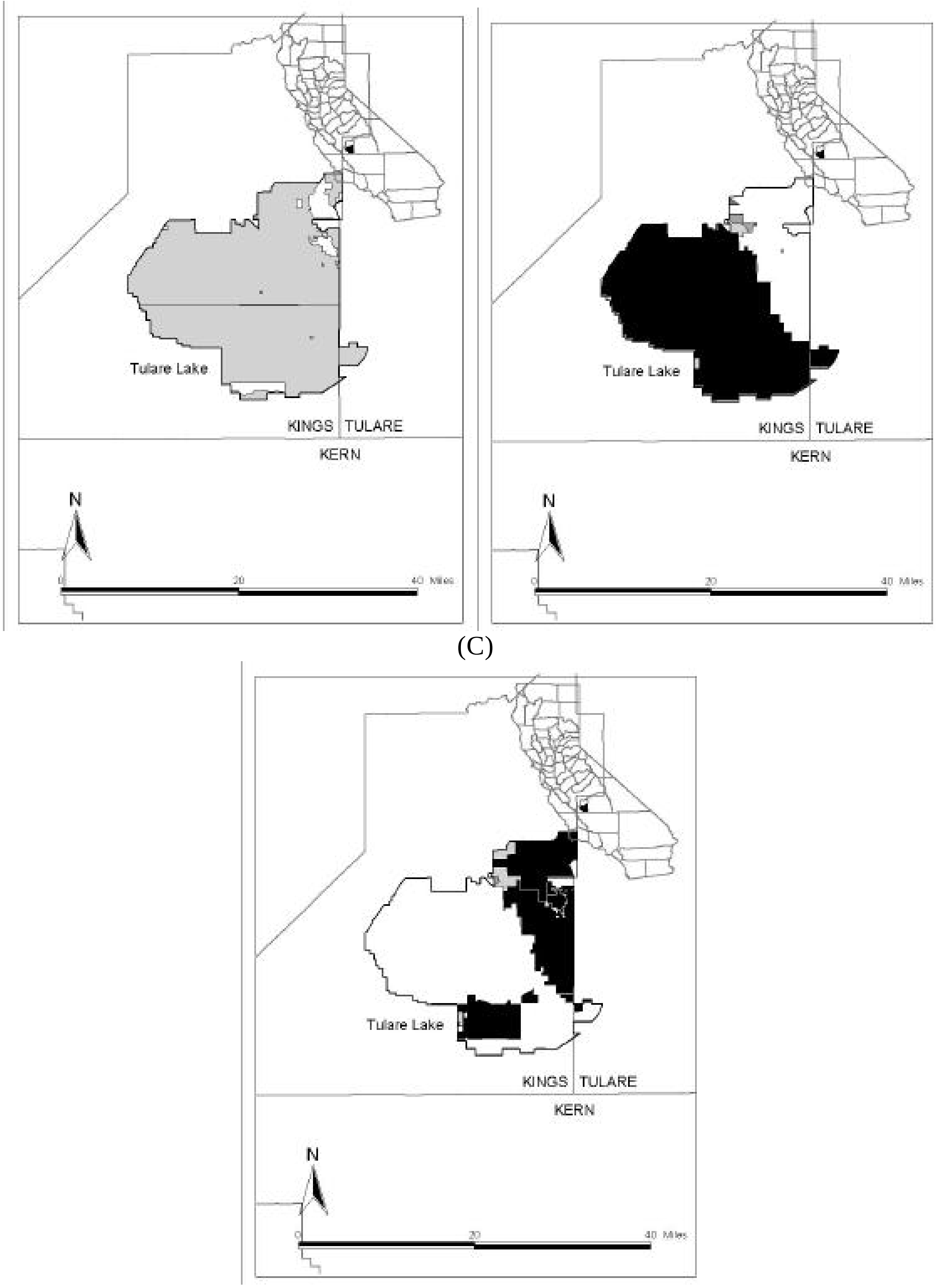

(A) (B)

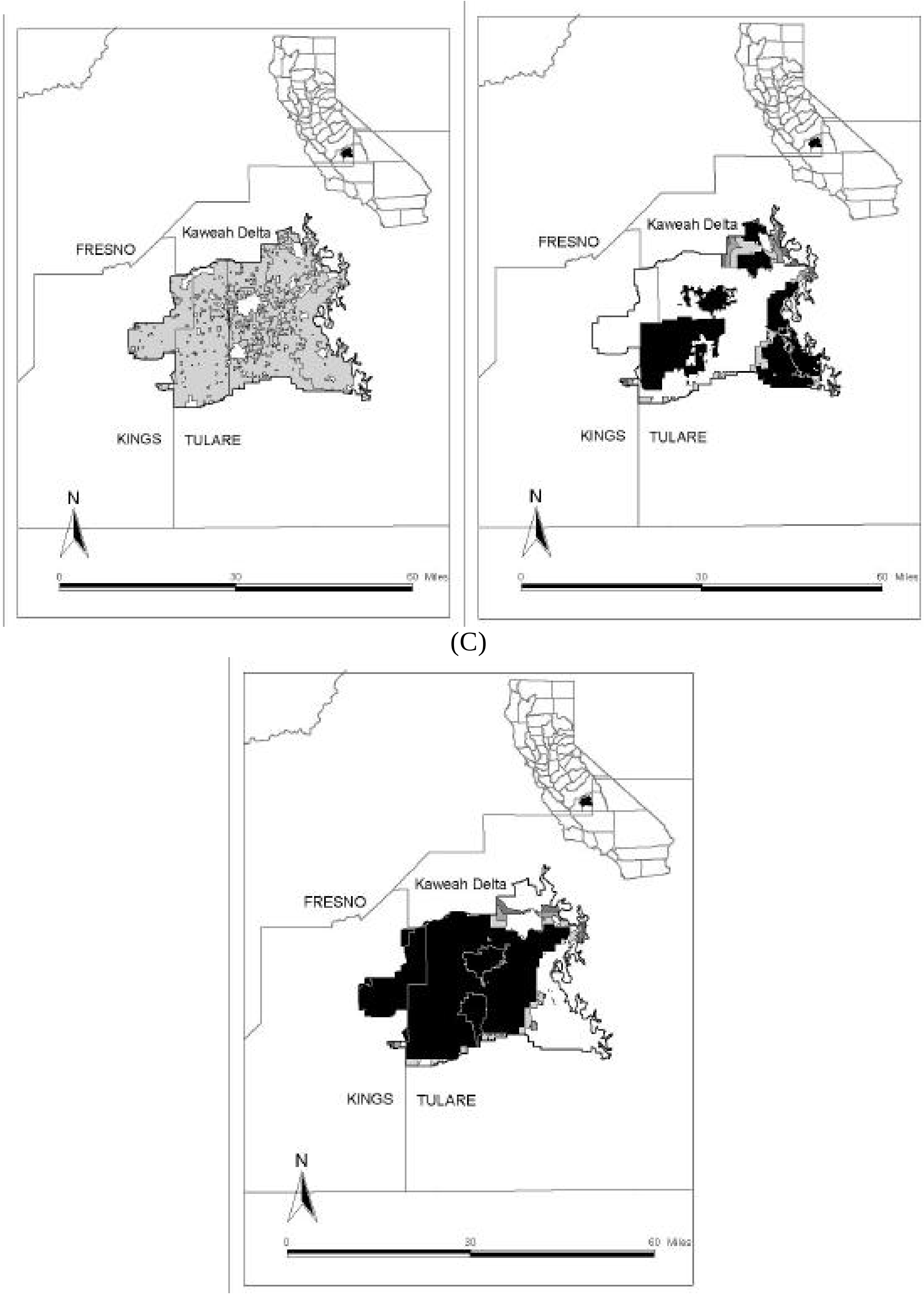
Figure A.43: DAU 241, Tulare Lake, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of State Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)


(A)

(B)

(C)

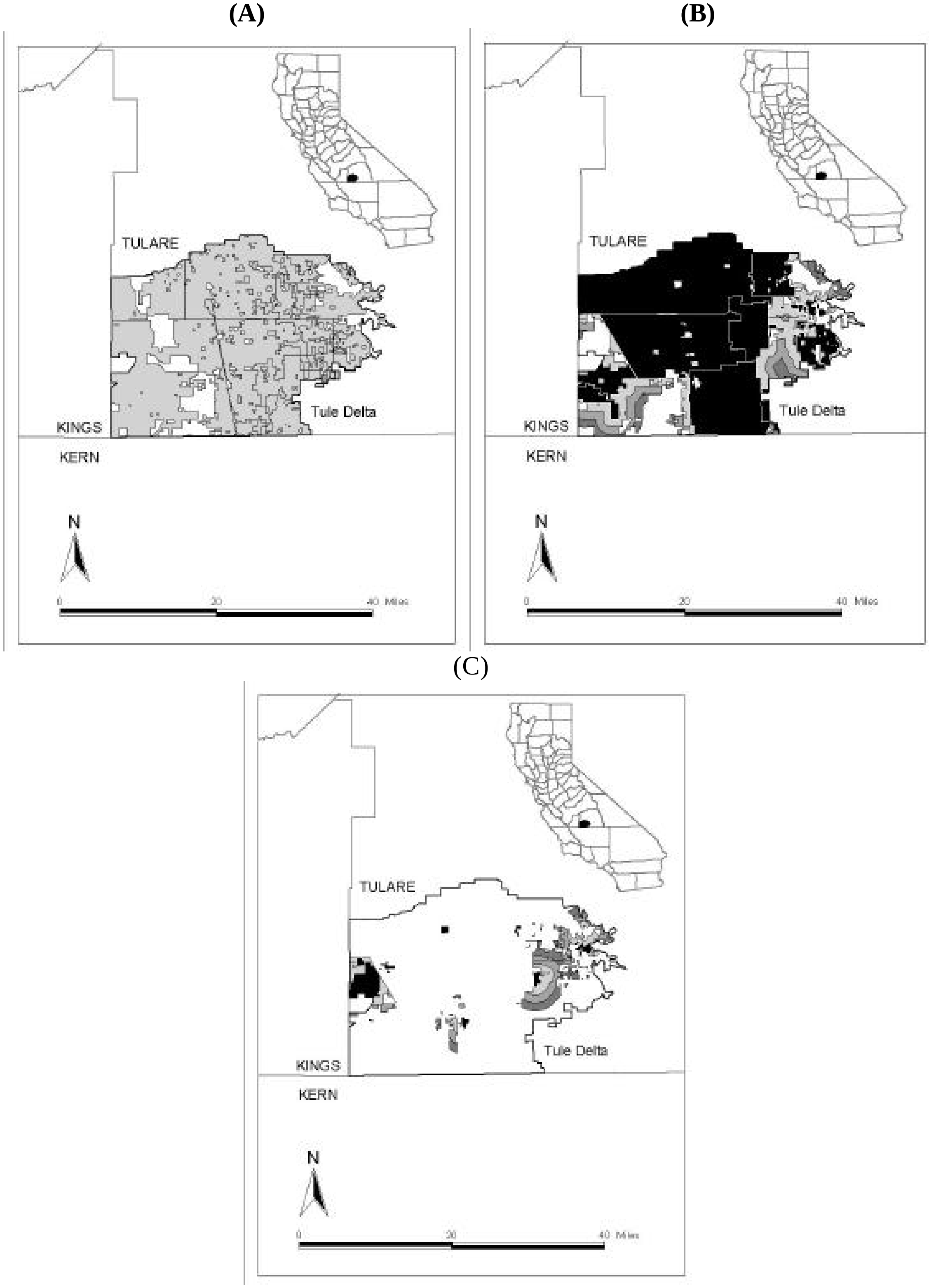
Figure A.44: DAU 242, Kaweah Delta, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A) (B)

(C)

Figure A.45: DAU 243, Tule Delta, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)



(A)

(B)

(C)

Figure A.46: DAU 244, Westlands, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B)

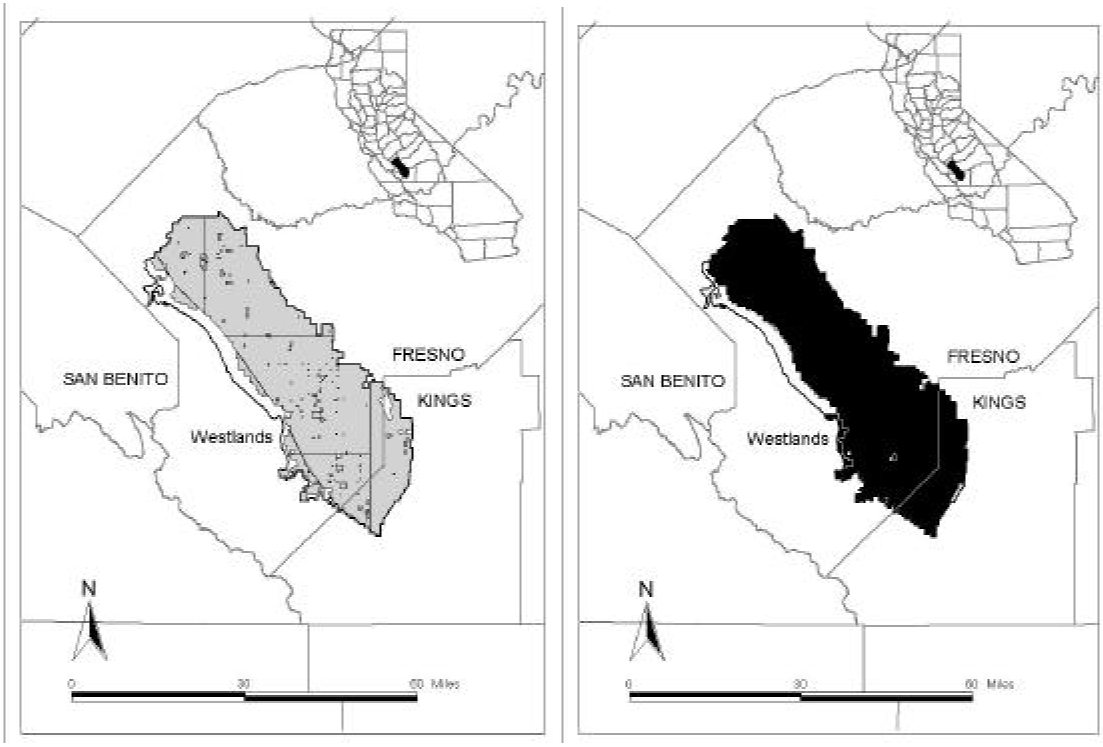

(A) (B)

Figure A.47: DAU 245, Kettleman Plain, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (C), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (D)

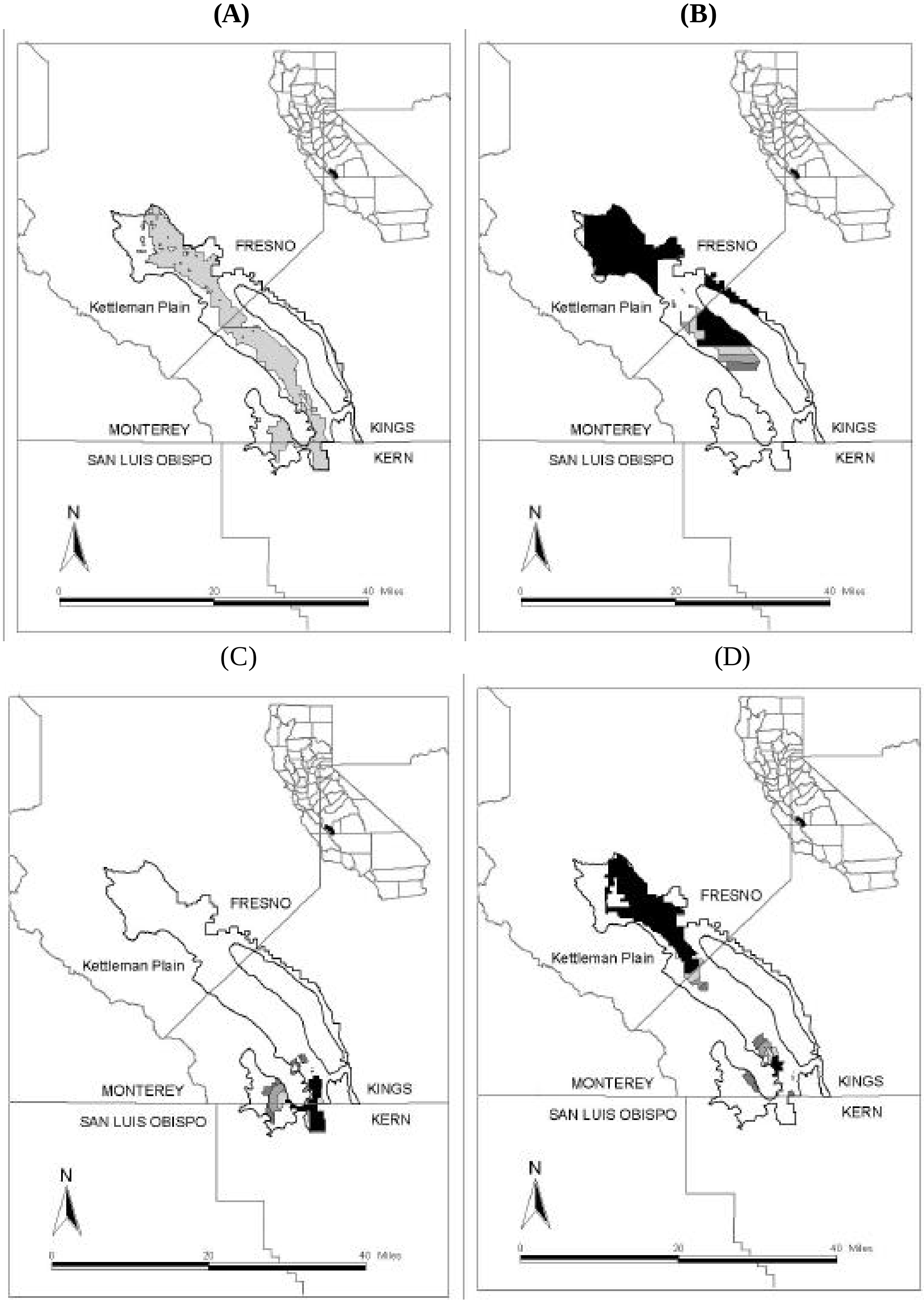
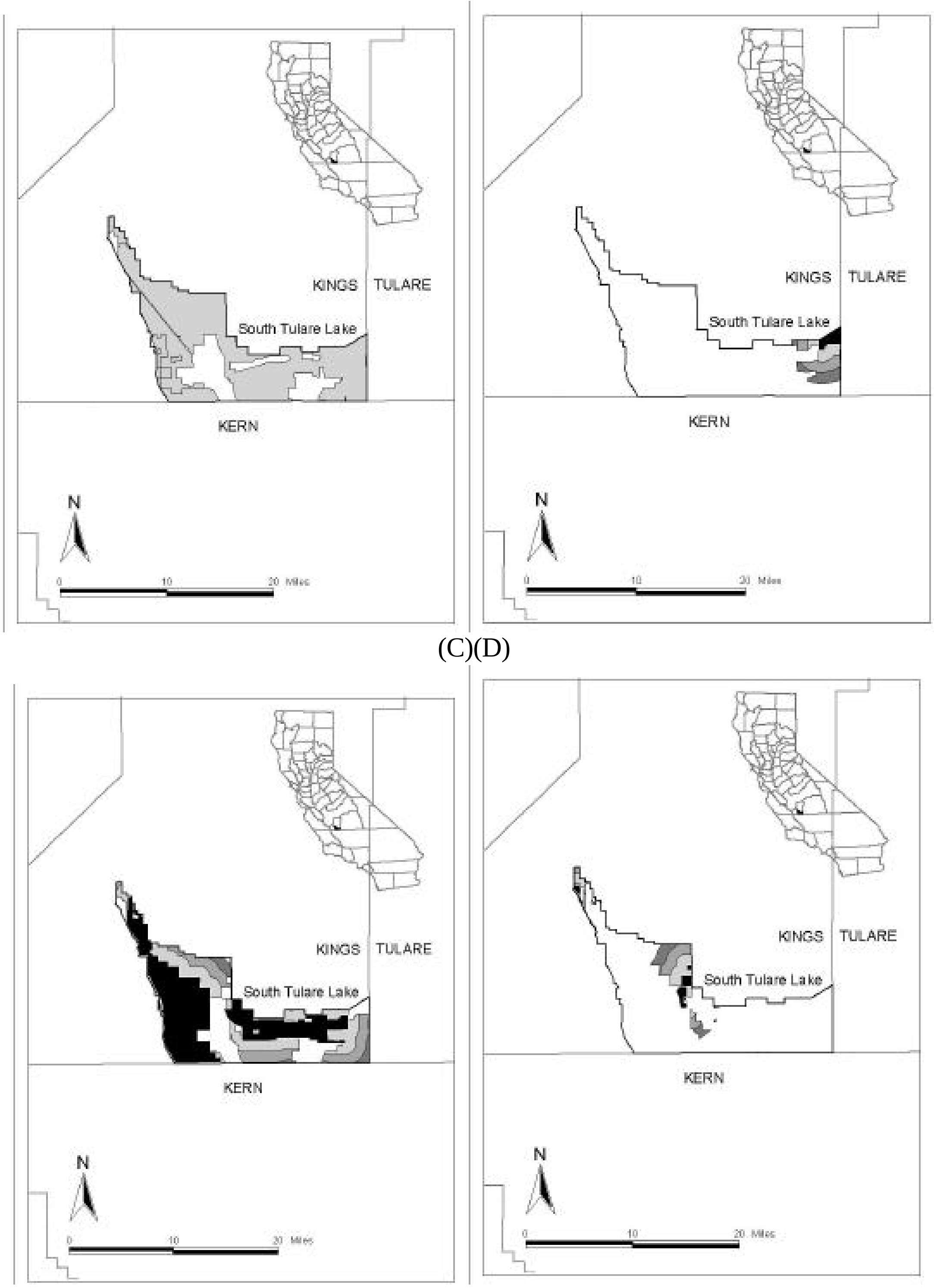
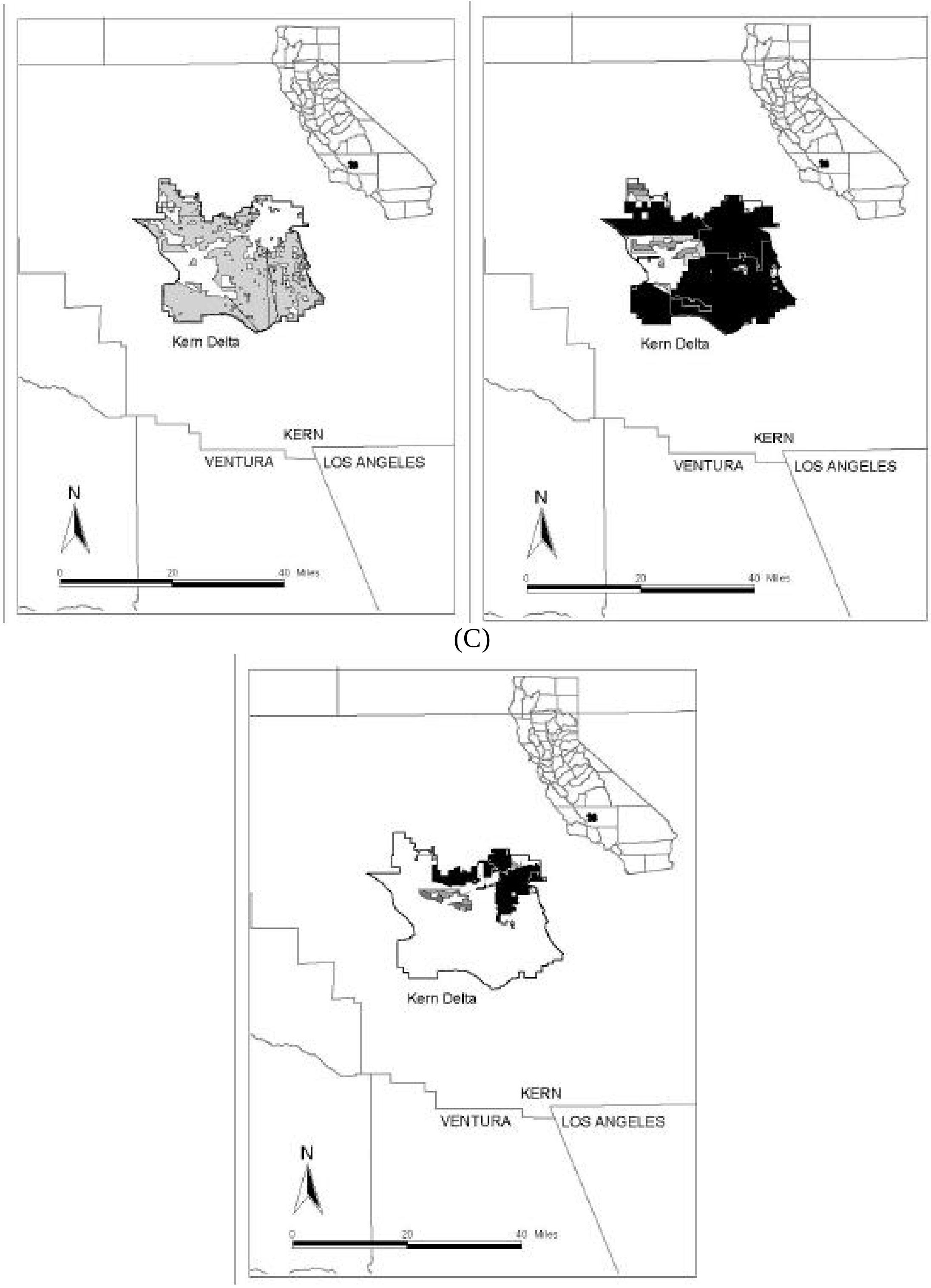

(A)
(B)
(C)
(D)

Figure A.48: DAU 253, South Tulare Lake, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (C), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (D)


(A) **(B)**

(C)(D)

Figure A.49: DAU 254, Kern Delta, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of State Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

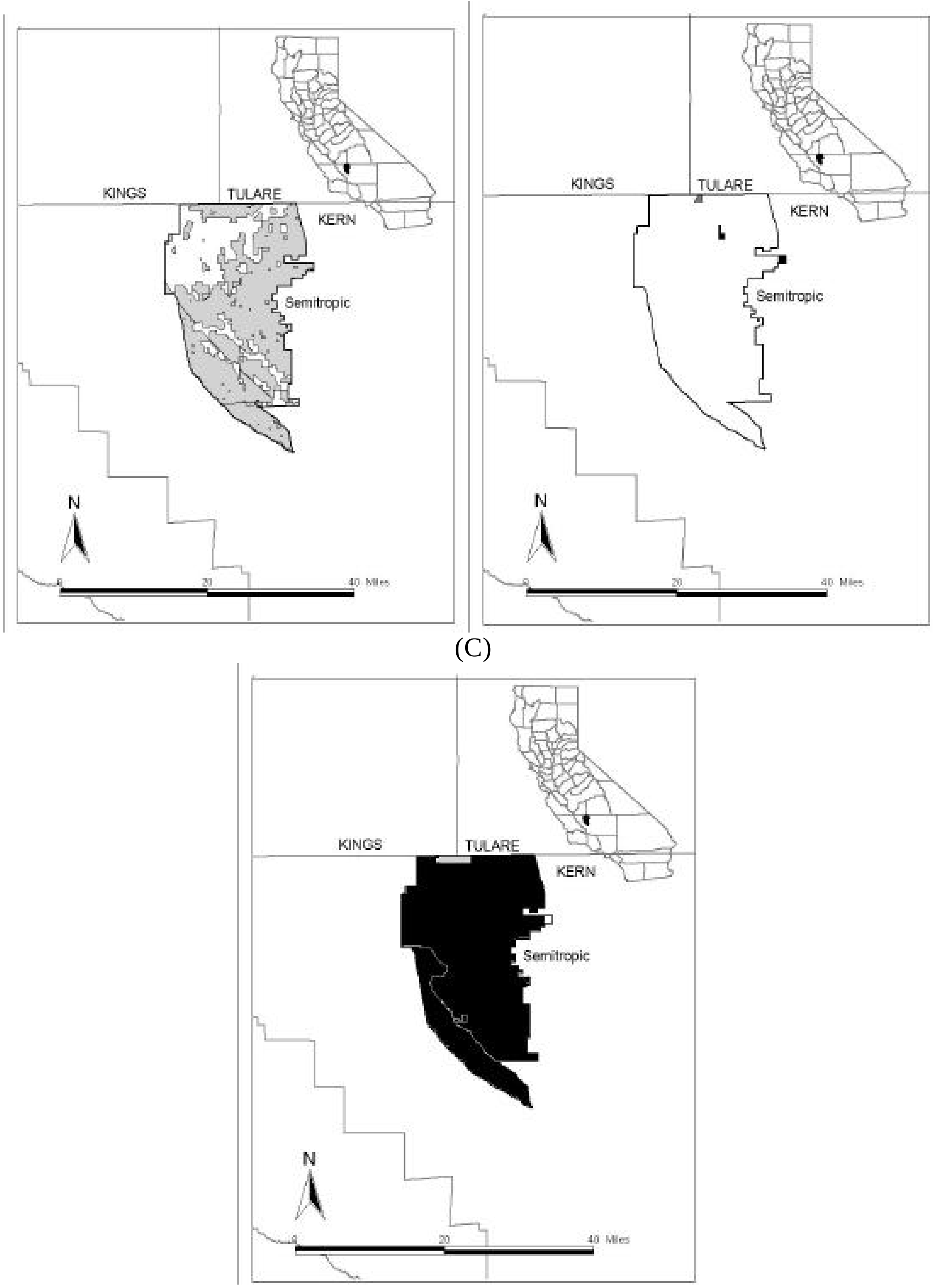


(A) **(B)**

(C)

Figure A.50: DAU 255, Semitropic, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (C)

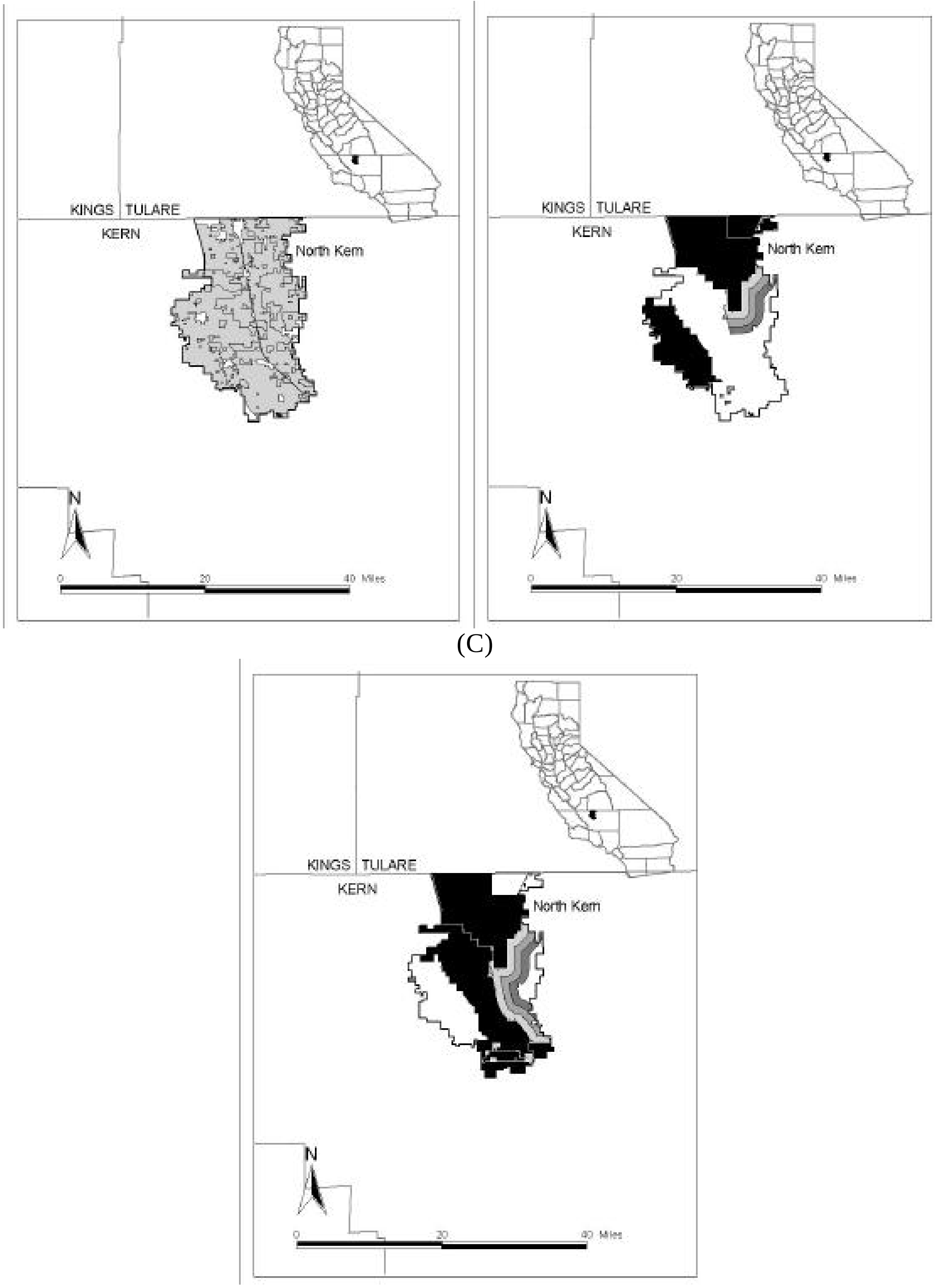
(A) **(B)**



(C)

Figure A.51: DAU 256, North Kern, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

(A) **(B)**



(C)

Figure A.52: DAU 257, Northeast Kern, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of Private Water Districts (C)

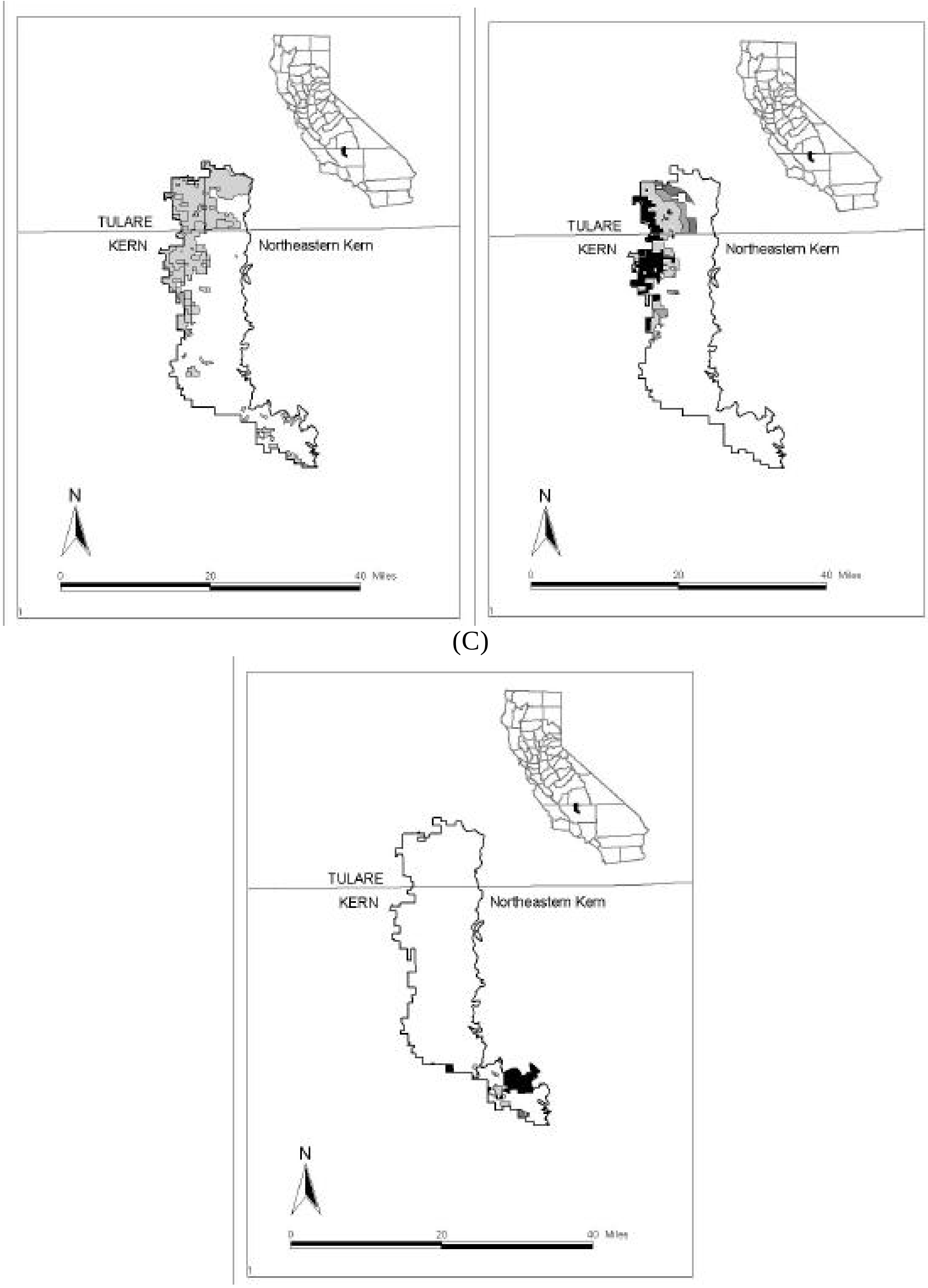
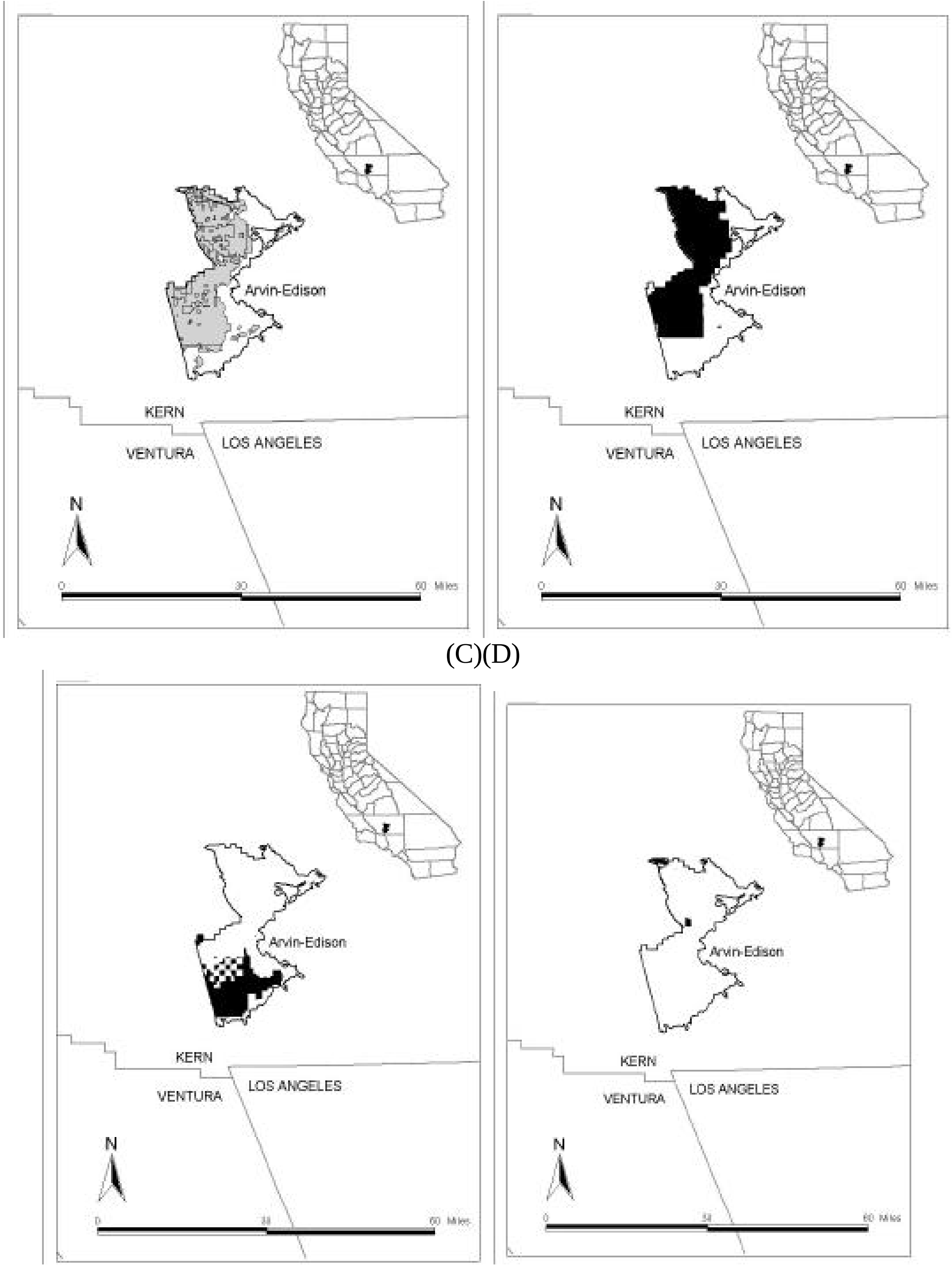


Figure A.53: DAU 258, Arvin-Edison, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (C), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (D)



(A) (B)

(C)(D)

Figure A.54: DAU 259, Antelope Plain, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of State Water Districts (B)

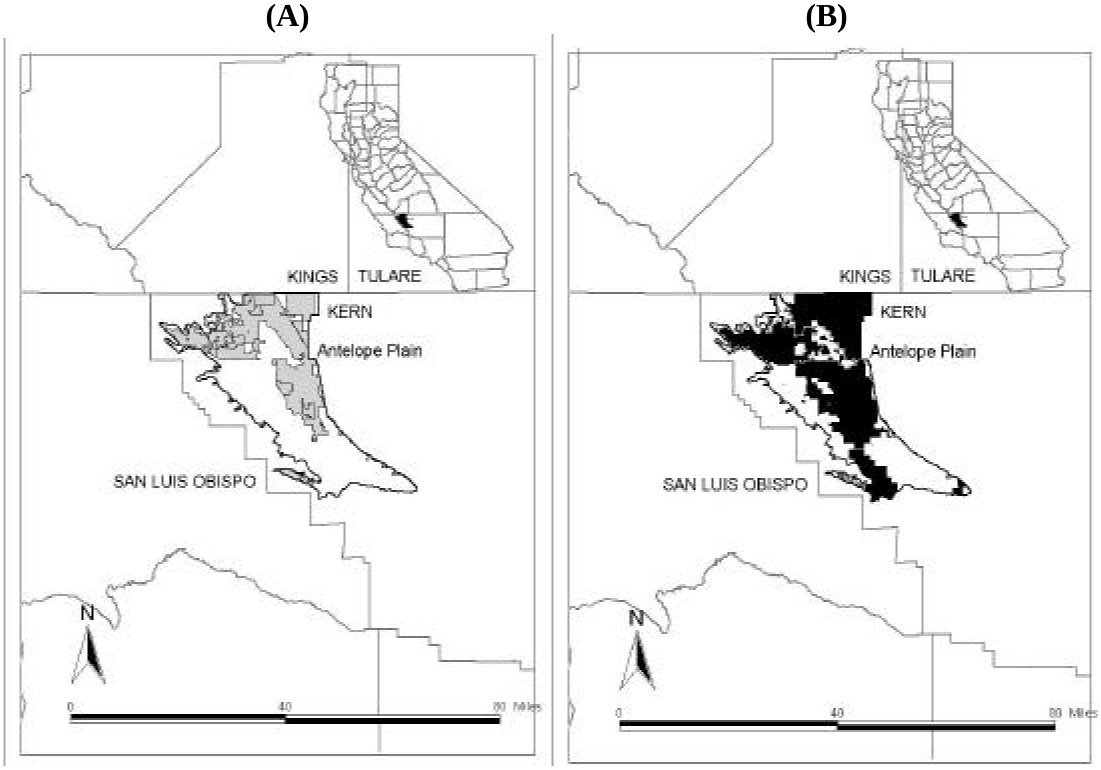
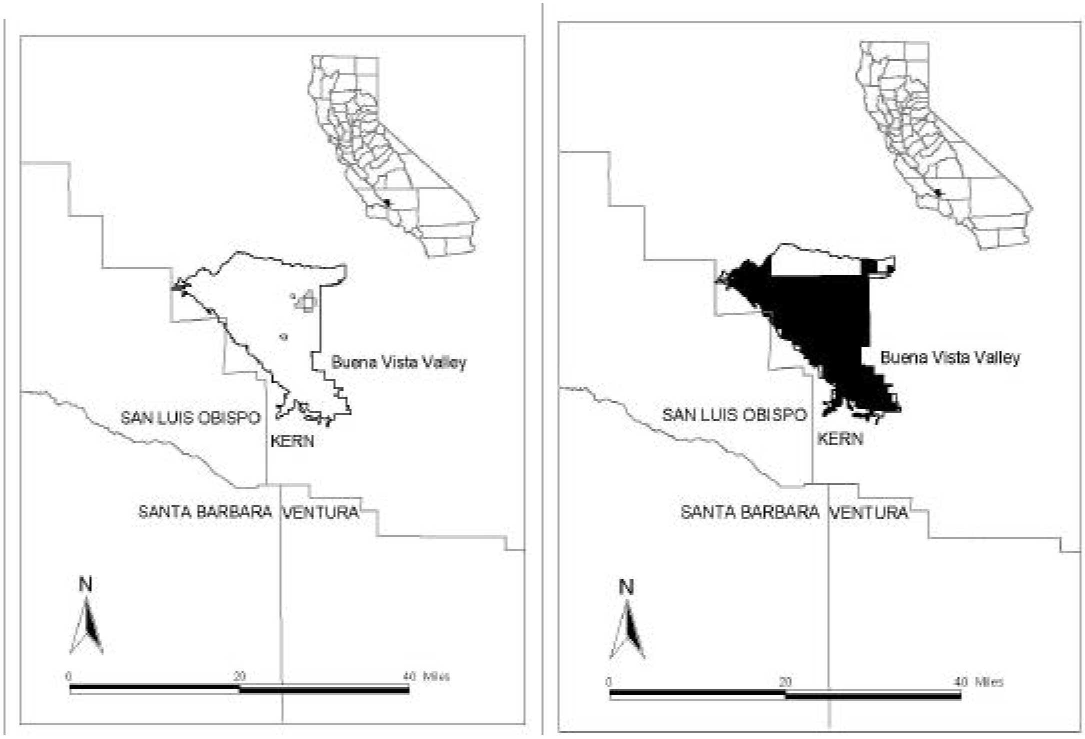

(A) (B)

Figure A.55: DAU 260, Buena Vista Valley, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of State Water Districts (B)



(A)

(B)

Figure A.56: DAU 261, Wheeler Ridge-Maricopa, Irrigated Agricultural Areas (A), Unincorporated Irrigated Land within 1(░), 2(▒) and 3(▓) Miles of Federal Water Districts (B), Unincorporated Irrigated Land within 1 (░), 2(▒) and 3(▓) Miles of State Water Districts (C)

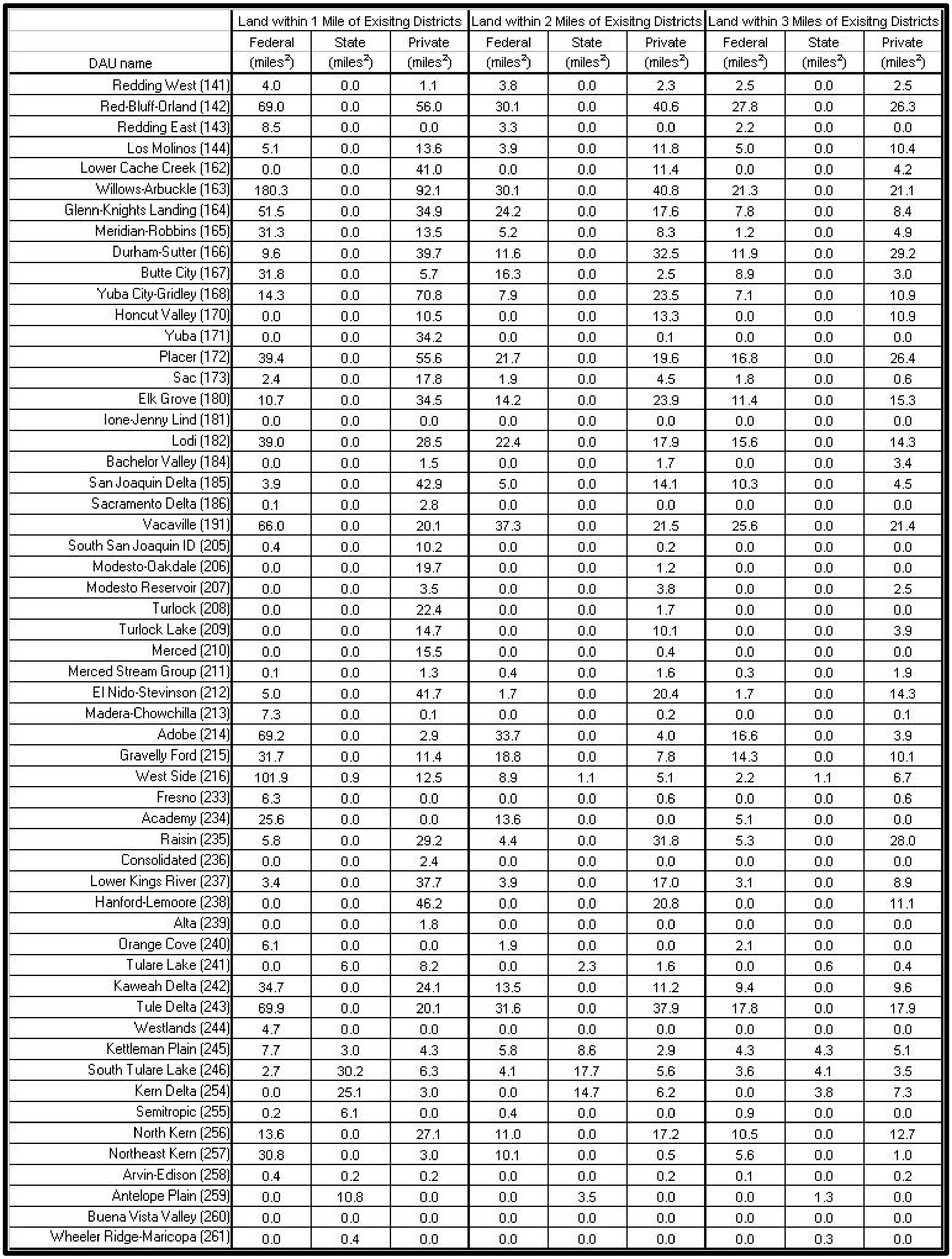

(A) (B)

(C)

Appendix B:

Tabular Summary of the Spatial Analysis Conducted to Determine the Amount of Unincorporated Irrigated Land Located within 1, 2 and 3 Miles of the Federal, State and Private Water Districts Found in the 56 Central Valley Detailed Analysis Units

Table B.1: Amount of Unincorporated Irrigated Land within 1, 2 and 3 Miles of Water Districts in the 56 Central Valley DAUs

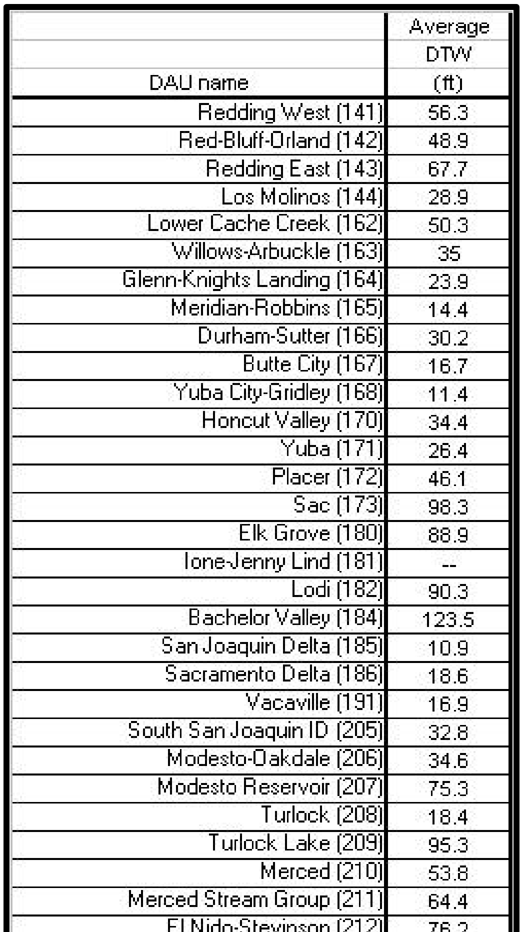


	Land within 1 Mile of Exisitng Districts			Land within 2 Miles of Exisitng Districts			Land within 3 Miles of Exisitng Districts		
DAU name	Federal (miles^2)	State (miles^2)	Private (miles^2)	Federal (miles^2)	State (miles^2)	Private (miles^2)	Federal (miles^2)	State (miles^2)	Private (miles^2)
Redding West (141)	4.0	0.0	1.1	3.8	0.0	2.3	2.5	0.0	2.5
Red-Bluff-Orland (142)	69.0	0.0	56.0	30.1	0.0	40.6	27.8	0.0	26.3
Redding East (143)	8.5	0.0	0.0	3.3	0.0	0.0	2.2	0.0	0.0
Los Molinos (144)	5.1	0.0	13.6	3.9	0.0	11.8	5.0	0.0	10.4
Lower Cache Creek (162)	0.0	0.0	41.0	0.0	0.0	11.4	0.0	0.0	4.2
Willows-Arbuckle (163)	180.3	0.0	92.1	30.1	0.0	40.8	21.3	0.0	21.1
Glenn-Knights Landing (164)	51.5	0.0	34.9	24.2	0.0	17.6	7.8	0.0	8.4
Meridian-Robbins (165)	31.3	0.0	13.5	5.2	0.0	8.3	1.2	0.0	4.9
Durham-Sutter (166)	9.6	0.0	39.7	11.6	0.0	32.5	11.9	0.0	29.2
Butte City (167)	31.8	0.0	5.7	16.3	0.0	2.5	8.9	0.0	3.0
Yuba City-Gridley (168)	14.3	0.0	70.8	7.9	0.0	23.5	7.1	0.0	10.9
Honcut Valley (170)	0.0	0.0	10.5	0.0	0.0	13.3	0.0	0.0	10.9
Yuba (171)	0.0	0.0	34.2	0.0	0.0	0.1	0.0	0.0	0.0
Placer (172)	39.4	0.0	55.6	21.7	0.0	19.6	16.8	0.0	26.4
Sac (173)	2.4	0.0	17.8	1.9	0.0	4.5	1.8	0.0	0.6
Elk Grove (180)	10.7	0.0	34.5	14.2	0.0	23.9	11.4	0.0	15.3
Ione-Jenny Lind (181)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lodi (182)	39.0	0.0	28.5	22.4	0.0	17.9	15.6	0.0	14.3
Bachelor Valley (184)	0.0	0.0	1.5	0.0	0.0	1.7	0.0	0.0	3.4
San Joaquin Delta (185)	3.9	0.0	42.9	5.0	0.0	14.1	10.3	0.0	4.5
Sacramento Delta (186)	0.1	0.0	2.8	0.0	0.0	0.0	0.0	0.0	0.0
Vacaville (191)	66.0	0.0	20.1	37.3	0.0	21.5	25.6	0.0	21.4
South San Joaquin ID (205)	0.4	0.0	10.2	0.0	0.0	0.2	0.0	0.0	0.0
Modesto-Oakdale (206)	0.0	0.0	19.7	0.0	0.0	1.2	0.0	0.0	0.0
Modesto Reservoir (207)	0.0	0.0	3.5	0.0	0.0	3.8	0.0	0.0	2.5
Turlock (208)	0.0	0.0	22.4	0.0	0.0	1.7	0.0	0.0	0.0
Turlock Lake (209)	0.0	0.0	14.7	0.0	0.0	10.1	0.0	0.0	3.9
Merced (210)	0.0	0.0	15.5	0.0	0.0	0.4	0.0	0.0	0.0
Merced Stream Group (211)	0.1	0.0	1.3	0.4	0.0	1.6	0.3	0.0	1.9
El Nido-Stevinson (212)	5.0	0.0	41.7	1.7	0.0	20.4	1.7	0.0	14.3
Madera-Chowchilla (213)	7.3	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.1
Adobe (214)	69.2	0.0	2.9	33.7	0.0	4.0	16.6	0.0	3.9
Gravelly Ford (215)	31.7	0.0	11.4	18.8	0.0	7.8	14.3	0.0	10.1
West Side (216)	101.9	0.9	12.5	8.9	1.1	5.1	2.2	1.1	6.7
Fresno (233)	6.3	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
Academy (234)	25.6	0.0	0.0	13.6	0.0	0.0	5.1	0.0	0.0
Raisin (235)	5.8	0.0	29.2	4.4	0.0	31.8	5.3	0.0	28.0
Consolidated (236)	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0
Lower Kings River (237)	3.4	0.0	37.7	3.9	0.0	17.0	3.1	0.0	8.9
Hanford-Lemoore (238)	0.0	0.0	46.2	0.0	0.0	20.8	0.0	0.0	11.1
Alta (239)	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Orange Cove (240)	6.1	0.0	0.0	1.9	0.0	0.0	2.1	0.0	0.0
Tulare Lake (241)	0.0	6.0	8.2	0.0	2.3	1.6	0.0	0.6	0.4
Kaweah Delta (242)	34.7	0.0	24.1	13.5	0.0	11.2	9.4	0.0	9.6
Tule Delta (243)	69.9	0.0	20.1	31.6	0.0	37.9	17.8	0.0	17.9
Westlands (244)	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kettleman Plain (245)	7.7	3.0	4.3	5.8	8.6	2.9	4.3	4.3	5.1
South Tulare Lake (246)	2.7	30.2	6.3	4.1	17.7	5.6	3.6	4.1	3.5
Kern Delta (254)	0.0	25.1	3.0	0.0	14.7	6.2	0.0	3.8	7.3
Semitropic (255)	0.2	6.1	0.0	0.4	0.0	0.0	0.9	0.0	0.0
North Kern (256)	13.6	0.0	27.1	11.0	0.0	17.2	10.5	0.0	12.7
Northeast Kern (257)	30.8	0.0	3.0	10.1	0.0	0.5	5.6	0.0	1.0
Arvin-Edison (258)	0.4	0.2	0.2	0.0	0.0	0.2	0.1	0.0	0.2
Antelope Plain (259)	0.0	10.8	0.0	0.0	3.5	0.0	0.0	1.3	0.0
Buena Vista Valley (260)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wheeler Ridge-Maricopa (261)	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.3	0.0

Appendix C:

Tabular Summary of the Depth to Water Observed in Wells Located in the Agricultural Areas of the 56 Central Valley DAUs

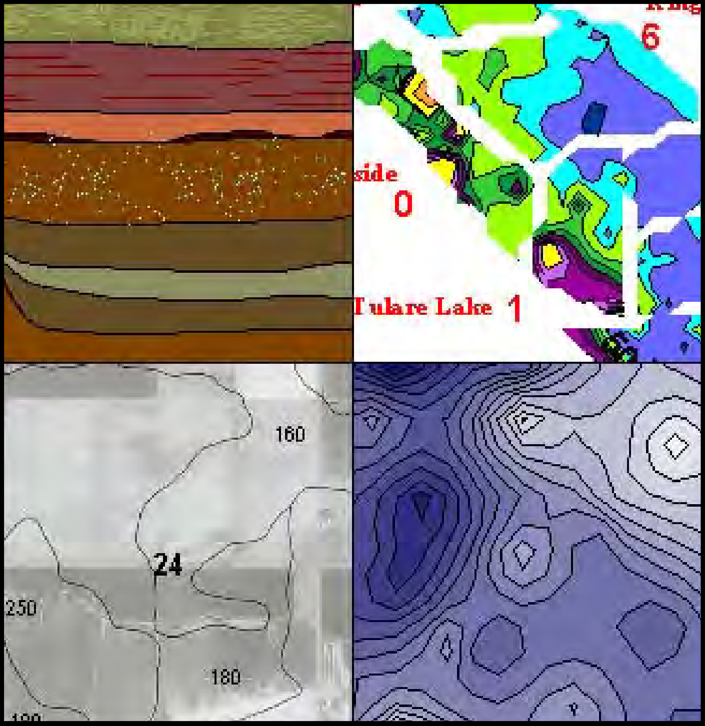
Table C.1: Average Fall 1999 Depth to Water in DWR Water Level Survey Wells Found in the Agricultural Areas of the 56 Central Valley DAUs



DAU name	Average DTW (ft)
Redding West (141)	56.3
Red-Bluff-Orland (142)	48.9
Redding East (143)	67.7
Los Molinos (144)	28.9
Lower Cache Creek (162)	50.3
Willows-Arbuckle (163)	35
Glenn-Knights Landing (164)	23.9
Meridian-Robbins (165)	14.4
Durham-Sutter (166)	30.2
Butte City (167)	16.7
Yuba City-Gridley (168)	11.4
Honcut Valley (170)	34.4
Yuba (171)	26.4
Placer (172)	46.1
Sac (173)	98.3
Elk Grove (180)	88.9
Ione-Jenny Lind (181)	--
Lodi (182)	90.3
Bachelor Valley (184)	123.5
San Joaquin Delta (185)	10.9
Sacramento Delta (186)	18.6
Vacaville (191)	16.9
South San Joaquin ID (205)	32.8
Modesto-Oakdale (206)	34.6
Modesto Reservoir (207)	75.3
Turlock (208)	18.4
Turlock Lake (209)	95.3
Merced (210)	53.8
Merced Stream Group (211)	64.4
El Nido-Stevinson (212)	76.2
Madera-Chowchilla (213)	102.5
Adobe (214)	177.6
Gravelly Ford (215)	80.6
West Side (216)	19.4
Fresno (233)	51.8
Academy (234)	89.5
Raisin (235)	97.2
Consolidated (236)	47.8
Lower Kings River (237)	128.6
Hanford-Lemoore (238)	65.2
Alta (239)	31.7
Orange Cove (240)	20.8
Tulare Lake (241)	112
Kaweah Delta (242)	56.3
Tule Delta (243)	103.8
Westlands (244)	206.4
Kettleman Plain (245)	425.5
South Tulare Lake (246)	134.1
Kern Delta (254)	96.3
Semitropic (255)	139.2
North Kern (256)	266.7
Northeast Kern (257)	343
Arvin-Edison (258)	279.3
Antelope Plain (259)	79.1
Buena Vista Valley (260)	105
Wheeler Ridge-Maricopa (261)	187.6

SYSTEM-WIDE CONJUNCTIVE WATER MANAGEMENT

THE HYDROGEOLOGIC SUITABILITY OF POTENTIAL GROUNDWATER BANKING SITES IN THE CENTRAL VALLEY OF CALIFORNIA



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This report and others from this project are available on-line from NHI's website at www.n-h-i.org or contact the Natural Heritage Institute at the address below.

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The Natural Heritage Institute is a non-profit natural resource conservation organization composed of technical and legal specialists and dedicated to the improvement of the laws and institutions that manage our natural heritage both domestically and internationally.

APPENDICES

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1.0 Introduction

This report is one product of a technical investigation to design a **Central Valley System-Wide Conjunctive Water Management Program** under an emerging partnership that includes the U.S. Bureau of Reclamation and a consortium of other public water management agencies. As envisioned by this program, conjunctive use entails the integration of groundwater banking with reservoirs that would be reoperated to generate the source water. Other products of the investigation that are now available include:

- ***Feasibility Study of a Maximal Program of Groundwater Banking in California*** (January 1999), which includes an overview of the project and three pilot feasibility studies.
- ***Designing Successful Groundwater Banking Programs In The Central Valley: Lessons From Experience*** (August 2001), which includes extensive analysis of legal and institutional constraints and solutions.

These and other project documents can be viewed and downloaded from the Natural Heritage Institute's website at www.n-h-i.org.

Subject to the availability of financial resources, forthcoming products will include reports on:

- "*In lieu*" groundwater banking site analysis
- Design specifications for local groundwater banking institutions
- The potential for reoperating reservoirs to generate source water for groundwater banking and to restore downstream fluvial processes
- Analysis of institutional, land use, infrastructure, environmental and other factors bearing upon siting decisions for groundwater banks
- Results of "gaming" analysis of a series of conjunctive use configurations in the Central Valley
- Economic optimization analysis
- A final feasibility report and strategic plan

This work is animated by the widespread realization that conjunctive water management will be a prominent feature of California's water future because it is an environmentally acceptable (indeed, environment-enhancing) and cost-competitive way to improve the reliability of water supplies for all sectors. Thus, groundwater banking has emerged as a management concept that can garner broad-based support. As a storage enhancement strategy, groundwater banking is an attractive alternative to many who are reluctant to endorse an ambitious expansion of the state's surface storage infrastructure. Storage increases associated with groundwater banking offer the potential to increase the yield of the California water system—an attractive prospect to the state's water user community. Indeed, the CalFed Record of Decision assigns a larger role to groundwater storage (500,000–1,000,000 acre-feet) than to any of the surface storage options in its plan to increase water supplies. Notably, however, the RoD gives priority to conjunctive use projects that are developed for local benefit and is silent regarding the source of the water to be banked. It is difficult to see how that vision would create new yield not otherwise available in the system. By contrast, the system-wide investigation, of which this report is a part, is oriented toward system-wide benefits (including benefits that accrue in the locale where groundwater banking occurs) and would generate new yield by integrating the water storage with existing reservoirs that would be reoperated so as to increase the space available to capture a larger fraction of annual runoff.

Groundwater banking must, as a practical necessity, be developed with the cooperation and consent of overlying landowners, groundwater appropriators, water districts and groundwater management authorities. Indeed, the recharge and recovery operations will generally be conducted by such local interests. Increasingly those communities that have historically relied on groundwater pumping to meet their needs realize that the best way to assure that local benefits flow from potential groundwater banking projects is to be involved in the project selection and design processes. The apparent convergence of interest between those charged with assuring California's future water supplies and those charged with managing local groundwater resources creates a climate where attempts are being made to identify the most promising groundwater banking opportunities in advance of the design and implementation of actual projects.

As with any water management initiative, the translation of a promising concept into a viable project relies upon a rigorous analysis of site-specific opportunities and constraints. To determine how best to link reservoirs that would provide the recharge water, with groundwater banking sites that would store it, with project beneficiaries who would use it, in a way that proves universally beneficial, it is of course necessary to investigate the most suitable groundwater banking sites. There are many dimensions to that puzzle. To itemize the most prominent factors, the most suitable sites will be those where:

- The target aquifer has the best physical characteristics for the storage and retrieval of banked groundwater;
- The aquifer does not interact with surface water bodies (unless such interaction is a desired characteristic);
- The overlying water districts or groundwater management authority is willing to operate the banks and where effects on unincorporated groundwater users can be avoided;
- The existing patterns of groundwater use in the vicinity of the project are compatible with groundwater banking;
- The legal and institutional setting governing groundwater management, use and export is most congenial;
- The recharge, extraction and conveyance facilities will not conflict with existing land uses;

- The manipulation of groundwater levels will not adversely affect important habitats, crops or structures;
- The project can be easily linked to a water distribution network;
- The project is located down gradient of river reaches through which it is feasible to re-establish geomorphically beneficial peak flows;
- The project is located within the same sub-basin as the demand center that it is intended to serve (so as to minimize the need to transfer the banked water across the delta); and
- The costs of storing and recovering water are relatively attractive.

This report focuses on the first factor only, namely the hydrogeologic suitability of potential groundwater banking sites in the Central Valley. In limiting the scope of the report to this factor, we fully recognize that hydrogeologic suitability may not be the ultimate arbiter of where groundwater banking projects will prosper. The full suite of opportunities and constraints that will bear on any final project selection, as itemized above, will be the subject of other reports emanating from this project. Perhaps most predominant of those is the local receptivity as shaped by the legal and institutional settings of current groundwater utilization—this is treated at length in the companion report, ***Designing Successful Groundwater Banking Programs in the Central Valley: Lessons from Experience***, published by the Natural Heritage Institute in 2001.

Also, in limiting our scope to the Central Valley, we acknowledge that promising groundwater banking opportunities exist both in the Bay Area and on the Southern California Coastal Plain. Our assumption is that these opportunities will be pursued by the water management agencies that overlie those sites as part of their own local resource planning efforts. Here we are attempting to focus on potential groundwater banking projects that through integration with the overall California water system could improve that system's performance, but which are less likely to be included in purely local resource planning initiatives. These sites are located primarily in the Central Valley.

We also need to be clear that the scope of this hydrogeologic suitability analysis is limited to one of several modes of recharging groundwater: active recharge through percolation of water from ponds at the land surface that overlie the aquifer in which water will be stored. Water introduced to these ponds will percolate under gravity through any intervening unsaturated material prior to entering into groundwater storage. Another strategy, which is not treated in this report, involves introducing banked water directly to groundwater storage via wells screened in the target aquifer material. A third approach to groundwater banking is called *in lieu* groundwater banking. Under this approach, historic users of groundwater are provided with a new or expanded supply of surface water that decreases their need to pump groundwater. Groundwater that goes unpumped is considered banked (site suitability analysis for this type of groundwater banking technique will be the subject of a forthcoming report from this investigation). A fourth emerging concept focuses on rivers that will undergo dramatic shifts in their flow regimes as part of ecosystem restoration efforts. In theory, any additional seepage through the bed of these rivers that percolates down to the underlying aquifer system could be considered banked.

Each of the approaches is characterized by technical considerations that define its suitability for a particular location. If, for example, the aquifer targeted for groundwater banking is located below layers of low permeability material, injection wells would represent a more viable option for conveying water to storage than recharge ponds. If such an area has already experienced substantial development of groundwater wells, it might be particularly well-suited for an *in lieu* banking arrangement. For instance, the Tuscan formation below Butte County is highly suitable for *in lieu* groundwater storage because it is overlain with a thick layer of tight geologic material and is already utilized for irrigation. This report focuses exclusively on groundwater banking via recharge ponds. We have limited the scope of our analysis in full recognition that other types of groundwater banking projects are possible, and potentially important, in California. However, we chose to focus on recharge ponds based on several factors:

- The largest existing groundwater banking projects in California, of which the Kern Water Bank is the best known, have generally employed recharge ponds.
- Soil assemblages in the Central Valley, derived largely from the deposition of alluvial fans, often contain soils coarse enough to support recharge ponds.
- While vertical stratification of thin water bearing and flow retarding aquifers does exist in parts of the Central Valley, deep alluvial aquifers receiving recharge from overlying percolation are fairly widespread.

Within this limitation in scope, however, this report provides a methodology to compare sites in the Central Valley in terms of their hydrogeologic suitability for groundwater banking via recharge ponds. Our methodology relies upon utilizing a core set of available data related to geology, groundwater quality, soils and hydrology to develop a Hydrogeologic Suitability Index, which like all indices is the product of both analysis and judgment. In developing this index we were driven by the desire to create a uniform template against which all potential groundwater banking sites could be compared—tempered by the recognition that site-specific factors and data limitations generally complicate the application of a uniform standard. We acknowledge these complications, and make appropriate assumptions in response, because waiting until the definitive information is available to complete our analysis, if ever, is unacceptable in the accelerated state of water planning initiated by the RoD.

One significant complication in applying a single index across the Central Valley stems from the fact that hydrogeologic conditions in the Sacramento and San Joaquin Valleys differ. While regions of prolonged groundwater overdraft characterize the San Joaquin Valley, resulting in the creation of substantial cones of depression, aquifers in the Sacramento Valley are not typically impacted by overdraft and large cones of depression are less common in this region. This difference has implications for the sequence of water storage and recovery that could be implemented as part of a program of groundwater banking. In general, dewatered aquifer space is available for immediate groundwater storage in portions of the San Joaquin Valley while aquifer storage in the Sacramento Valley would generally have to follow the groundwater recovery required to create storage space. The hydrologic parameters useful in evaluating the hydrogeologic suitability of groundwater banking under these two conditions are not identical. As a result, we developed a core index that includes information on geology, groundwater quality and soils that can be applied in both the Sacramento and San Joaquin Valleys, and an extended index that draws upon hydrologic information for use solely in the San Joaquin Valley.

Even in applying the index within the Sacramento or the San Joaquin Valley, however, we confronted the challenge of assigning appropriate weighting factors for the parameters under consideration. These assignments are certainly open to alternative interpretations. To allow for that, we have crafted a methodology that allows others to insert weighting factors that reflect their own judgments or preferences. The result is a spreadsheet that can be manipulated based on any number of assumptions regarding appropriate weighting factors. If suitably disaggregated data is available, the index is also scalable so that it could be applied to the comparison of promising groundwater banking sites within a single county as easily as it has been applied across the Sacramento or San Joaquin Valleys in this report.

We hope this flexibility and scalability will make the index useful to a range of potential users in California. These could include: agency staff charged with prioritizing the range of potential groundwater banking sites across the Central Valley, researchers examining the interactions between groundwater banking and other water management objectives such as flood control and ecosystem restoration, local and private resource managers deciding whether or not a groundwater banking project they are contemplating offers strategic advantages to statewide water planners, and reservoir operators attempting to develop groundwater banking strategies that take into consideration all of the constraints and opportunities listed above. Thus, despite the limitations inherent in adopting an index approach, we trust that our study will provide information useful to all of these actors as they attempt to move the analysis of groundwater banking to a point where consideration of more refined site-specific details of promising sites becomes both necessary and appropriate.

This work is properly viewed as a first screen in identifying the most suitable groundwater banking sites. The scale of analysis is too coarse and the data uncertainties too significant to permit specific parcels of land to be specified as the best locations to construct groundwater recharge or extraction facilities. Nor would we presume so far without the assent of such landowners. Indeed, the uncertainties inherent in the analysis point out areas where additional research carried out with limited public resources would prove beneficial. Refinement of the information on the heterogeneity of geologic and associated aquifer hydraulic properties in the areas that appear most suitable for groundwater banking is a direct benefit that can flow from the development of the index. Continued investment in water quality data acquisition may also be warranted at promising sites as much of the information currently available is decades old. Finally the analysis can lend focus to more targeted analysis that includes the other factors, itemized above, that will necessarily bear upon the selection of optimal sites. With the funds earmarked for conjunctive use beginning to flow from the CalFed Program,Proposition 13 funding, and other federal and state resources, the analysis behind the development of the index can provide useful on where to utilize research dollars intended to facilitate the increasing adoption of conjunctive use as a viable water management strategy.

Two things are clear: 1) the potential for conjunctive water management to contribute to a more secure water supply in California is too large to ignore, and 2) one of the factors that most inhibits the realization of this potential is the lack of definitive information on hydrogeologic suitability. Uncertainties in this regard engender fear of unintended consequences within those communities currently most reliant upon groundwater. Fear creates resistance among those who have most to gain from this water management technique—those landowners who control the aquifers and could manage them as a local public good and those public officials charged with managing our limited water supplies. If we wait for the optimal list of conjunctive use projects, developed from unimpeachable information, to appear, we may miss the opportunity to realize the enormous potential of conjunctive water management. Imperfect as it is, we hope that this document, along with others published by the investigation, will assist as we push toward the realization of actual conjunctive use projects.

2.0 Identification of Potential Groundwater Banking Sites

As stated in Section 1.0, differences in the hydrologic conditions encountered in the Sacramento and San Joaquin Valleys militate in favor of applying the Hydrogeologic Suitability Index separately to these two regions. In both regions a core index, based on geology, groundwater quality and soils considerations, can be applied. An extended index that takes into account hydrologic information can be applied in the San Joaquin Valley. Before applying either index, however, a list of potential groundwater banking sites in both regions of the Central Valley must be developed.

A number of inventories of potential groundwater banking sites have been assembled in recent years. Many of these were synthesized in the list of potential sites reported in *A Feasibility Study of a Maximal Scale Program of Groundwater Banking in California* published by the Natural Heritage Institute in 1999. A less inclusive list of the sites judged to be most feasible from a technical and political vantage point were evaluated for recharge and recovery capacity in the February 2000 *Conjunctive Use Site Assessment* prepared by the Integrated Storage Investigation of the CALFED Bay-Delta Program. In general, these inventories have adopted a broad perspective, leading to the identification of rather large areas as potential banking sites (e.g., Yuba County or the Tuolumne/Merced Basin). A slightly more refined optic was adopted during the development of the Hydrogeologic Suitability Index. Here an attempt was made to identify the actual regions where measured groundwater levels reveal the opportunity to store water within dewatered aquifer material, or areas where in spite of the current high water table conditions, geologic conditions would favor an increase in aquifer management through more ambitious pumping and recharge.

The following steps were taken in the process of identifying potential groundwater banking sites in the Central Valley. Data from the Department of Water Resources semi-annual survey of wells was downloaded for Fall 1992. Using a contouring program, a groundwater head surface was developed for the entire Central Valley. Data from areas that exhibited groundwater head levels lower than that found in the surrounding area were examined in greater detail. Based primarily on the geometry of the mapped depressions, a qualitative assessment was made as to whether the depressions represented water table declines or comparatively low piezometric surfaces in deep water-bearing horizons. In general, water table declines were deemed to exhibit continuity with levels observed in the majority of nearby wells while low piezometric surface readings were associated with “bulls eye” type depressions that exhibited little correlation with nearby wells. Once depressions that appeared to be related to declines in the regional water table were identified, the second step in site identification involved examining soils maps to identify promising sites for recharge basins. This examination, which also relied upon qualitative analysis of existing data, sought to identify four-square-mile blocks of land with the most “promising” assemblage of soils. This involved looking for blocks dominated by sandy soils with a minimum of clay. While this step did not involve statistical analysis of soil assemblages, it was generally possible to visually distinguish sites with generally coarse soil from those dominated by fine-grained material. The four-square-mile blocks of land located over what were considered to be water table depressions were selected as the potential groundwater banking sites.

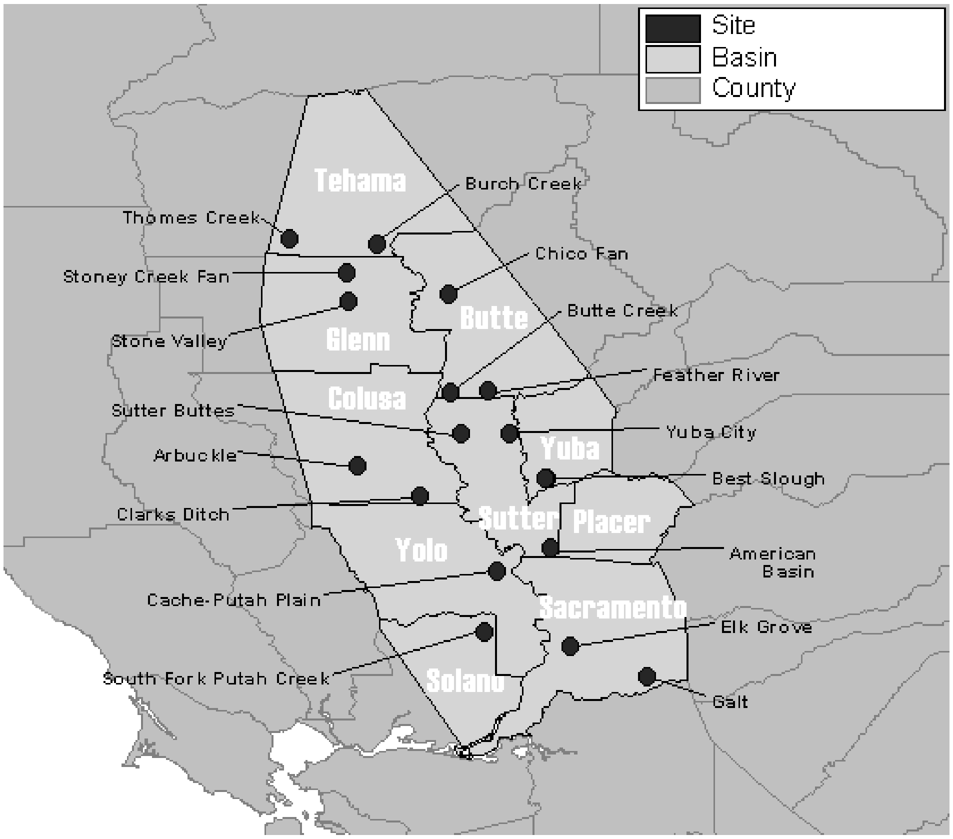
Viewed through this lens, several potential sites emerge within the broad regions previously defined. Figures 2.0.1 and 2.0.2 depict the locations of the sites that were ultimately selected for consideration in the Sacramento and San Joaquin Valleys, respectively. Information on the sites depicted in Figures 2.0.1 and 2.0.2 includes a site name, identifies the groundwater basin where the site is located and provides a reference to the site location based on the California State Land Survey system. The California Department of Water Resources delineated the groundwater basins.

The site names that appear in Figures 2.0.1 and 2.0.2 require some clarification. Information relevant to the Hydrogeologic Suitability Index is available at a variety of scales. In general, however, information on the characteristics of soils overlying potential groundwater banking sites is available at the finest scale (as fine as 1:20,000 in many soils surveys prepared by the United States Soil Conservation Service). In attempting to define important parameters associated with the soil characteristics at potential groundwater banking projects, four-square-mile land sections with the most attractive soil assemblages were identified in the region overlying targeted storage sites. The site names associated with each location are derived from prominent geographic features located near the selected land units. While these names may be less recognizable than Yuba County or the Tuolumne/Merced Basin, all information needed to locate the banking site selected for analysis are included in Figures 2.0.1 and 2.0.2.

In selecting the sites depicted in Figures 2.0.1 and 2.0.2, we anticipate that many readers will find reasons to object to the inclusion of a particular site or the exclusion of another. We make no claim that the lists we developed are complete and comprehensive. We do feel, however, that we have created a sample that reasonably reflects the range of potential groundwater banking sites in the Central Valley. There are sites in the western Sacramento Valley that are associated with the flashy gravel-laden streams that emerge from the Coast Range Mountains. Sites on the east side of the Sacramento Valley are associated with large perennial streams that drain the granite-rich Sierra Nevada. In the San Joaquin Valley there are sites associated with rivers that issue to the Bay-Delta system and others that drain into the Tulare Lake Basin. The only region of the Central Valley not represented is the western San Joaquin Valley, a region plagued by poor groundwater quality that makes it less favorable to groundwater banking based on the use of recharge ponds.

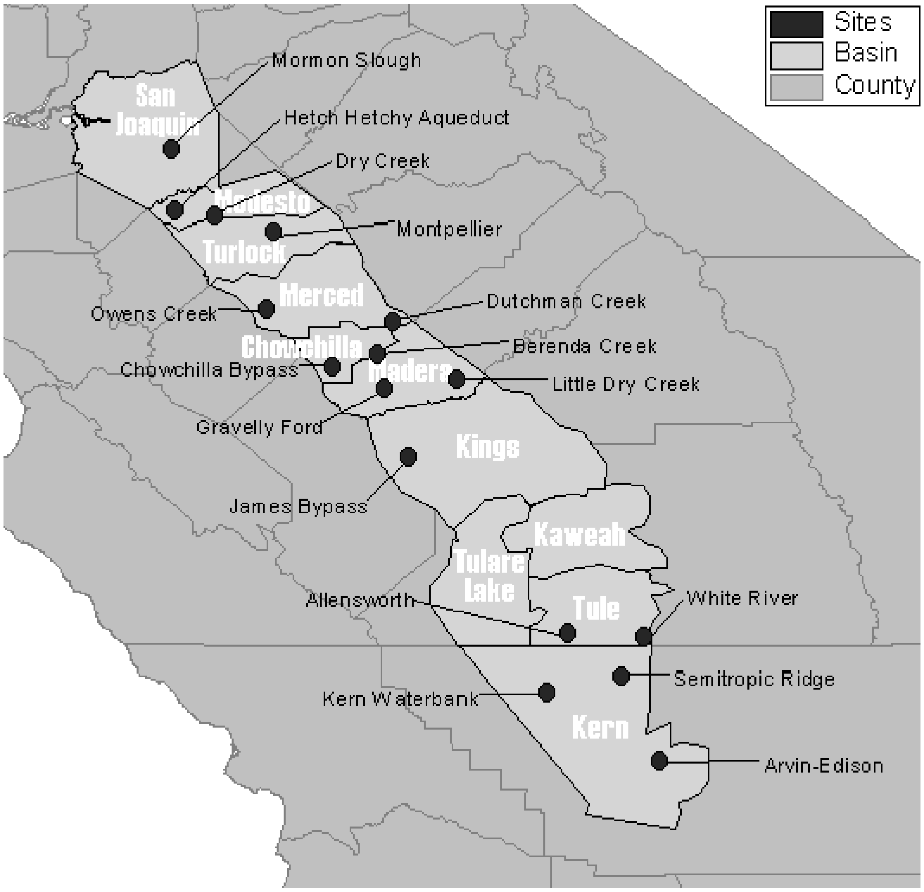
In addition, if others feel that additional sites should be added to the list, it is easy to do so in the spreadsheet developed as part of this project. It is simply a matter of defining the required parameter values and adding the site to the database.

Figure 2.0.1: Potential Groundwater Banking Sites in the Sacramento Valley



Site	Basin	Township, Range	Sections
Thomes Creek	Tehama	T24N, R5W	9, 10, 15, 16
Burch Creek	Tehama	T23N, R2W	17, 18, 19, 20
Stony Creek Fan	Glenn	T22N, R3W	19, 20, 29, 30
Stone Valley	Glenn	T21N, R3W	28, 29, 32, 33
Chico Fan	Butte	T21N, R1E	15, 16, 21, 22
Butte Creek	Butte	T17N, R1E	15, 16, 21, 22
Feather River	Butte	T17N, R2E	14, 15, 22, 23
Sutter Buttes	Sutter	T15N, R1E	1, 2, 11, 12
Yuba City	Sutter	T15N, R3E	4, 5, 8, 9
Arbuckle	Colusa	T14N, R3W	15, 16, 21, 22
Best Slough	Placer-Yuba	T13N, R4E	3, 4
		T14N, R4E	33, 34
Clarks Ditch	Colusa	T13N, R1W	21, 22, 27, 28
American Basin	Sutter	T11N, R4E	26, 27, 34, 35
Cache-Putah Plain	Solano-Yolo	T10N, R2E	24, 25
		T10N, R3E	19, 30
South Fork Putah Creek	Solano-Yolo	T7N, R2E	2, 3, 10, 11
Elk Grove	Sacramento	T7N, R5E	27, 28, 33, 34
Galt	Sacramento	T5N, R7E	1, 12
		T5N, R8E	6, 7

Figure 2.0.2: Potential Groundwater Banking Sites in the San Joaquin Valley



Site	Basin	Township, Range	Sections
Mormon Slough	San Joaquin	T1N, R7E	13, 24
		T1N, R8E	18, 19
Hetch Hetchy Aqueduct	Modesto	T3S, R8E	19, 20, 29, 30
Dry Creek	Modesto	T3S, R9E	25, 26, 35, 36
Montpellier	Turlock	T4S, R12E	19, 20, 29, 30
Owens Creek	Merced	T8S, R11E	13, 14, 23, 24
Dutchman Creek	Merced	T8S, R17E	31, 32
		T9S, R17E	5, 6
Berenda Creek	Chowchilla	T10S, R16E	21, 22, 27, 28
Chowchilla Bypass	Chowchilla	T11S, R14E	2, 3, 10, 11
Gravelly Ford	Madera	T12S, R16E	11, 12, 13, 14
Little Dry Creek	Madera	T11S, R19E	25, 26, 35, 36
James Bypass	Kings	T15S, R17E	23, 24, 25, 26
White River	Tule	T24S, R27E	22, 23, 26, 27
Allensworth	Tule	T24S, R24E	15, 16, 21, 22
Semitropic Ridge	Kern	T26S, R26E	13, 14, 23, 24
Kern Waterbank	Kern	T27S, R23E	10, 11, 14, 15
Arvin-Edison	Kern	T30S, R28E	21, 22, 27, 28

3.0 Description of the Sub-Index Parameters

As mentioned in Section 1.0, conditions encountered in the Sacramento and San Joaquin Valleys are sufficiently distinct to warrant the application of different versions of the Hydrogeologic Suitability Index. One major difference is the degree to which aquifers in the two regions have been drawn down. While the San Joaquin Valley is characterized by substantial cones of depression, surface aquifers in the Sacramento Valley generally exhibit water tables that closely track the land surface profile. This makes it more difficult to speculate how these aquifers would respond to the more intensive management that would accompany groundwater banking. As such, a sub-index related to hydrologic conditions in the target aquifers has been applied only at sites in the San Joaquin Valley.

In both locations, however, a core set of data related to geology, groundwater quality and soils can be used to develop relevant sub-indices. This section describes the parameters included in the core index and a methodology for evaluating their impact on the overall hydrogeologic suitability of potential groundwater banking sites. One of the central challenges in developing these sub-indices was to assign values to their various components. In the geology sub-index, for example, we consider the permeability of water-bearing geologic formations below potential groundwater banking sites. In making this consideration we reviewed numerous reports describing the geology of the target basins. These reports often used terms such as the formation is “highly” or “moderately” permeable. In a few cases, ranges of permeability values were also given, many of which were quite broad.

We did not attempt to translate these observations into a rigorous geo-statistical representation of permeability across the Central Valley. Instead we sought to develop associations between what previous researchers called highly, moderately and non-permeable materials and the range of actual permeability values that were occasionally reported in the literature. While this qualitative approach did not allow us to distinguish between two formations that were deemed to be highly permeable to find the “most promising sites”, it did allow us to confidently sort the geologic formations into broad categories useful in defining the “most promising sites”. This level of refinement was in keeping with the fact that the hydrogeologic suitability of a potential site will be only one factor influencing its ultimate selection for a groundwater banking project. A similar qualitative approach was taken in defining values for certain components of other core sub-indices. While this approach may seem cursory to some, we feel it is in keeping with the intent of this effort, which is to provide insight useful in identifying a suite of potential sites that merit the type of closer consideration that will lead to more refined comparisons among potential groundwater banking project locations.

3.1 Geology Sub-Index

Perhaps the most important factor in evaluating the hydrogeologic suitability of potential groundwater banking sites is the nature of the underlying geologic formations. The characteristics of these formations will control the amount of water that can be stored within a given volume of aquifer material and the ease with which water can be recharged to and extracted from the water-bearing formations. Clearly, an unconsolidated, uncemented, coarse-grained alluvial formation would offer easier access to larger storage volumes than a consolidated, fine-grained, lacustrian formation.

3.1.1 Geology Sub-Index Parameters

Having reviewed some of the voluminous geologic literature available for the Central Valley (see the Geology portion of Section 7.0: References), we decided to employ three parameters to characterize the geologic suitability of formations underlying potential sites for groundwater banking: permeability, the presence of paleosols, and the presence of geologic structures that could enhance or detract from aquifer storage potential. While many other parameters could have been used, we limited our selection based on the availability of data across most of the sites under consideration and on our desire to use parameters that were likely to be independent of one another. For example, we originally considered using both the percent coarse-grained material and the degree of cementation and consolidation of the target aquifer as parameters in the geology sub-index. These were ultimately discarded because they are likely correlated with the permeability of the aquifer formation. Details on the final set of parameters are presented in the following paragraphs.

Permeability

Permeability describes the ease with which water can flow through geologic material. Measured in units of length per time, permeability affects the rate at which water can percolate into the geologic material for storage and also the rate at which it can be pumped out in recovery. In general, the higher the estimated permeability, the better the yield of wells installed in a formation. Increases in well yield would facilitate the recovery of water stored in a potential groundwater banking site, enhancing that site's suitability. Permeability was scored based on textual descriptions of formations from the references cited in Section 7.0. Formations were described as being impermeable, moderately permeable, or highly permeable.

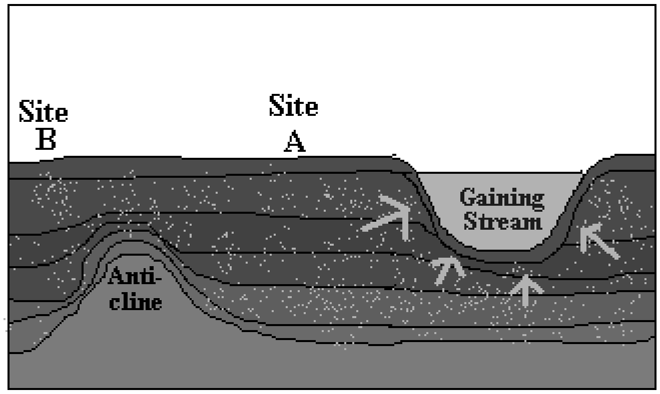
Paleosols

The deposition of sedimentary formations is not a continuous process. At certain periods the forces contributing to deposition are absent, resulting in long-term exposure of the material at the surface of the formation. During these periods, soil development can occur. Paleosols, or fossil soils, are old soil layers that are buried in a geologic formation when the forces contributing to deposition resume. As a high concentration of clay minerals and the potential for hardpan development exist in the paleosols, they can impede the vertical flow of water through a formation. Such an impediment could restrict the access to storage available in the geologic formations below the paleosol layer, thereby reducing the suitability of a potential groundwater banking site.

Geologic Structure

Tectonic forces acting on sedimentary deposits can create structures within a formation. Depending on their location and orientation, folds and faults can serve to isolate stored groundwater from the surrounding aquifer. Figure 3.1.1 depicts a situation where the presence of an anticline in folded sedimentary deposits could isolate stored groundwater from a gaining stream that conveys water away from aquifer storage. By separating Site B from the stream's influence, the anticline structure increases the suitability of that site relative to Site A.

Figure 3.1.1: Influence of Geologic Structure on Geologic Suitability



Groundwater banked at Site A, which is in proximity to a gaining stream, would be subject to higher losses than water banked at Site B, which is isolated from the stream by an anticline structure within the formation.

3.1.2 Geology Sub-Index Weighting Factors

Having described these parameters for each of the formations found below potential groundwater banking sites, we gave them a score on a scale from 0 to 10, with a score of 10 representing characteristics that would make a particular formation a suitable target for groundwater banking. Our scoring system is described in Table 3.1.1.

Having scored each of the parameters, a composite formation score was calculated based on Equation 3.1.

Table 3.1.1: Parameter Weighting Factors Used to Calculate the Geology Sub-Index

Component	0	5	10
Permeability	Impermeable	Moderately permeable	Highly permeable
Paleosols	Contains resistant paleosols	Contains some slightly resistant paleosols	No paleosols
Geologic Structure	Contains structural features that direct stored groundwater toward gaining streams	Contains no structural features	Contains structural features that isolate stored groundwater from gaining streams

$$\boxed{\text{Formation Score} = 2*(\text{Permeability}) + 0.5*(\text{Paleosols}) + (\text{Geological Structure})} \quad (3.1)$$

Given the relative importance of permeability in terms of evaluating the suitability of a formation for groundwater banking, it was assigned a weighting factor of 2. The existence of paleosols was assigned a weighting coefficient of 0.5 because, although they can act as barriers to the vertical movement of water, they tend to be described as thin and discontinuous in the Central Valley. The geology sub-index values are calculated as the sum of the scores for each of the formations underlying a particular groundwater banking site, weighted by the relative formation thickness within the top several hundred feet of the sub-surface (Equation 3.2). In the Sacramento Valley, several stratified formations were often encountered; in the San Joaquin Valley, undifferentiated alluvial deposits were the norm.

$$\boxed{\text{Geology Sub-Index} = \Sigma\,(\text{Formation Score}_A * \text{Formation Thickness}_A)} \quad (3.2)$$

The preceding equations point out the role that weighting factors play in the calculation of the Hydrogeologic Suitability Index. Scores for both the parameters and the formations rely upon somewhat arbitrary weighting factors. When a formation is ranked as highly permeable, it receives a score twice as high as a moderately permeable formation, and that difference in score is multiplied by 2 in calculating the formation score. It is here that another individual interested in groundwater banking could apply a different set of weighting factors in the spreadsheet developed for this project.

3.2 Water Quality Sub-Index

If water is stored at a potential groundwater banking site, it will commingle with the native groundwater. The quality of this native water will influence the ultimate quality of water stored in and recovered from the aquifer (the quality of stored water will also influence the quality of water available to existing groundwater users). This sub-index attempts to compare sites in terms of the quality of groundwater found at potential sites.

3.2.1 Water Quality Sub-Index Parameters

Four water quality components were selected based on their importance to both urban and agricultural water users and on the availability of data for the potential groundwater banking sites: arsenic, boron, lead and total dissolved solids. These parameters were defined using USGS National Water Information System (NWIS) data collected after 1/1/1970.

Arsenic (As)

Arsenic is a micronutrient for humans. However, long-term exposure to high concentrations of arsenic in drinking water can lead to many dangerous health problems including at least 8 different types of cancer (EPA website, 2001). Arsenic contained in groundwater generally comes from the natural weathering of the local geologic materials, although it can also result from anthropogenic sources such as industrial waste, arsenical pesticides and smelting operations (De Zuane, 1997). The maximum contaminant level for As enforced by the EPA is 50 ppb (or 50 mg/L), though this standard is currently under review and may be lowered to 10 ppb (or 10 mg/L) (EPA website, 2001).

Boron (B)

Boron is a micronutrient required in small amounts by both humans and plants. However, if the concentration of boron in groundwater is too high, it can be toxic for many commercially important crops in California. In general, water used for irrigation of boron-sensitive crops should contain less than 1.0 mg/L (or 1000 mg/L) to prevent toxicity.

Lead (Pb)

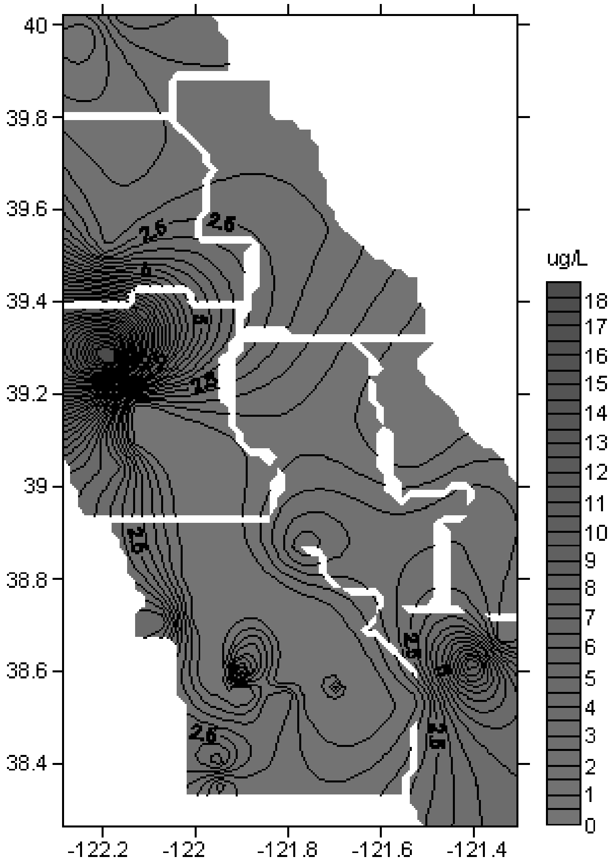
Lead is a metal that can be found in drinking water as a result of natural weathering of local ore deposits. Lead is extremely hazardous and can cause a multitude of health problems including stroke, kidney disease and cancer. It also disrupts normal physical and mental development in infants and children (EPA website, 2001). Due to these extreme effects, the EPA maximum contaminant level for lead is zero; however, the action level at which clean-up takes place is 15 ppb (or 15 mg/L) due to current technological and resource-oriented constraints (EPA website, 2001).

Total Dissolved Solids (TDS)

TDS is not a trace element like the other water quality parameters, but is a measure of the concentration of inorganic salts (primarily Ca, Mg, K, Na, bicarbonates, chlorides and sulfates) and organic material dissolved in water (WHO, 1993). Although there are no specific health problems or regulations associated with high TDS levels, the generally accepted limit for drinking water is 1000 mg/L (WHO, 1993). For TDS, the EPA sets the National Secondary Drinking Water Regulation, a non-enforceable guideline based on the cosmetic and aesthetic qualities of water, at 500 mg/l (EPA website, 2001).

Data gathered on each of these parameters (see the Water Quality portion of Section 7.0: References) reveal a fair amount of spatial variability across the Central Valley. As an example, measured lead concentrations in groundwater in the Sacramento Valley are shown in Figure 3.2.1. The most elevated levels were observed in Colusa and Sacramento Counties. Contour maps of the three other parameters reveal distinct patterns of spatial variability that could influence the selection of potential groundwater banking sites.

Figure 3.2.1: Lead Contour Map for the Sacramento Valley



3.2.2 Water Quality Sub-Index Weighting Factors

The raw water quality data for the four parameters above is listed in Appendix A. In order to convert these raw parameter values into a water quality sub-index, a method for assigning parameter scores between 1 and 10 was developed. As with the geology sub-index parameters, a score of 10 corresponds with conditions most favorable to groundwater banking. Table 3.2.1 describes the scores assigned to distinct ranges of raw parameter values. In each case, a score of 5 corresponds with the EPA-recommended level.

Table 3.2.1: Parameter Weighting Factors Used to Calculate the Water Quality Sub-Index

		Arsenic			Boron			Lead			TDS		
	Score	µg/L			µg/L			µg/L			mg/L		
Toxic	1	50.00	+		9000.00	+		15.00	+		1000.00	+	
	2	40.00	-	49.99	7000.00	-	8999.00	13.33	-	14.99	875.00	-	999.00
	3	30.00	-	39.99	5000.00	-	6999.00	11.67	-	13.32	750.00	-	874.00
	4	20.00	-	29.99	3000.00	-	4999.00	10.00	-	11.66	625.00	-	749.00
Recommended	5	10.00	-	19.99	1000.00	-	2999.00	8.33	-	9.99	500.00	-	624.00
	6	8.00	-	9.99	800.00	-	999.00	6.67	-	8.32	400.00	-	499.00
	7	6.00	-	7.99	600.00	-	799.00	5.00	-	6.66	300.00	-	399.00
	8	4.00	-	5.99	400.00	-	599.00	3.33	-	4.99	200.00	-	299.00
	9	2.00	-	3.99	200.00	-	399.00	1.67	-	3.32	100.00	-	199.00
	10	0.00	-	1.99	0.00	-	199.00	0.00	-	1.66	0.00	-	99.00

Scores for the individual parameters can be combined to calculate a composite water quality score, as in Equation 3.3. In this case no weighting factors have been employed, although someone interested in a particular parameter could weight that constituent accordingly in the spreadsheet developed as part of this effort.

$$\boxed{\text{Water Quality Score} = (\text{As Score}) + (\text{B Score}) + (\text{Pb Score}) + (\text{TDS Score})} \quad (3.3)$$

Below a particular groundwater banking site, two water quality scores may be of interest. The first corresponds with the water quality immediately below a potential groundwater banking site and reflects the short-term mixing between recharge water and native groundwater that occurs when they come into contact. Once a significant amount of recharge occurs and water is stored at a banking site for extended periods of time, the potential for longer-term mixing between stored water and the native groundwater extends over a much larger area. Over this time scale, it is the quality of the groundwater in the basin surrounding the potential banking site that is important. Using available data, basin groundwater quality scores were calculated by averaging all the data from the wells within the basin boundaries for a specific component. This same data was then used to create a contour map (similar to Figure 3.2.1) so the approximate water quality score at potential groundwater banking sites could be determined.

Our attempt to capture the full spectrum of potential mixing between banked water and native groundwater led us to define the two components of the water quality sub-index described in Equation 3.4.

$$\boxed{\text{Water Quality Sub-Index} = 1.5*(\text{Basin Score}) + (\text{Site Score})} \quad (3.4)$$

In this version of the water quality sub-index, the basin score was weighted more heavily than the site score. The heavier weighting on the basin score tends to stress the impact of long-term interactions between banked water and native groundwater. This is in keeping with the utility assigned to most banked groundwater in California—namely that it is to serve as a source of supplemental supply in the relatively infrequent dry and critical water years.

One final point that should be made regarding the water quality sub-index is that the data used to develop water quality contour maps come from wells screened at different depths. Ideally the vertical relationship between water quality observations should be considered along with their relative horizontal positions. We made an attempt to limit the vertical extent of water quality observations by excluding any samples that were noted as having been taken from below the Corcoran Clay in the San Joaquin Valley. As the screened interval in most sampled wells is neither known nor reported, it was difficult to introduce the vertical dimension into our water quality contour maps. Any attempt to screen the samples by depth would have proved much too expensive and time consuming to be undertaken in the current effort. This is another area where more specific analysis of potential sites will be required once the field of potential groundwater banking sites has been thinned.

3.3 Soils Sub-Index

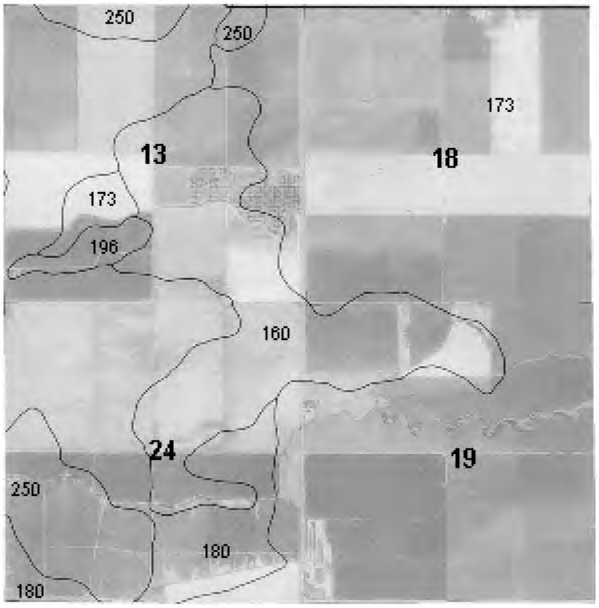
Soil characteristics exert a potentially important control on the overall hydrogeologic suitability of potential groundwater banking projects employing recharge ponds, since the physical properties of the soil profile may limit the percolation rate. Sites with low percolation rates will require larger basins in order to recharge a given volume of water, thereby increasing the overall cost of the project. If the soil chemistry at a site is poor, the quality of banked water might be degraded as it percolates from the recharge basin. In the extreme, problematic soils could be removed from a potential site prior to the construction of recharge basins. However, this would greatly increase the overall cost of the project, potentially making it less attractive with respect to other alternatives.

3.3.1 Soils Sub-Index Parameters

The main data source used to define parameters for this sub-index was the USDA soil survey series for California (see the Soils portion of Section 7.0: References). Each volume of the series covers an area of California (typically a single county) and is composed primarily of detailed maps showing aerial photographs overlain by the delineation of soils found in the area. An example (Figure 3.3.1) is an excerpt from the Soil Survey of San Joaquin County, California (McElhiney, 1992). The large font numbers that appear on the figure (13, 18, 24, 19) are the township and range sections associated with the California Public Lands Survey. The small number found within each soil polygon correlates to a soil type and a series of soil parameters. For example, 180 represents an area covered by Jackstone clay.

From the extensive list of parameters reported for each soil type, we selected four that we feel capture the impacts that the physical and chemical properties of a soil can exert on groundwater banking via recharge ponds: soil thickness, soil permeability, soil pH and the presence or absence of hardpans. These parameters were evaluated for each soil type encountered at potential groundwater banking sites according to the approach described in the following paragraphs.

Figure 3.3.1: Soil Survey Map of Mormon Slough (McElhiney, 1992)



Thickness

Each soil's thickness was recorded in inches and normalized relative to the maximum soil thickness encountered at the full suite of potential groundwater banking sites to generate a soil thickness score between 0 and 1. A thick soil will magnify any negative effects on percolation or water quality encountered as water flows through the soil column to the underlying aquifer. Similarly, a thick soil will magnify positive soil characteristics.

Permeability

Soil permeability is a measure of how easily and quickly water moves through a soil. The USDA soil surveys report permeability in a range in inches of water per hour. We took the average value of the range reported for each soil type encountered at the each of the potential groundwater banking sites and normalized it to arrive at a score between 0 and 1, where a value of 1 is desirable. In cases where no specific permeability value was provided, the permeability was estimated as a function of soil structure and clay content as per the National Soil Survey Handbook (USDA, 1999).

pH

Soil pH is a measure of the acidity of a soil. The USDA assigns categories to pH levels, and we assigned numerical values to the categories in order to include them in the soils sub-index, as shown below in Table 3.3.1. In this case, a neutral pH of 7 corresponds with component score of 1. Increasingly acidic and alkaline soils are awarded decreasing parameter scores. While not a perfect predictor for the types of chemical transformation water percolating from a recharge pond will undergo, pH is a good proxy for a number of potential water quality problems in the soil.

Table 3.3.1: pH Rating Scale

pH reading	USDA category	Suitability Index
3.5 - 4.4	Extremely acid	0
4.5 - 5.0	Very strongly acid	0.2
5.1 - 5.5	Strongly acid	0.4
5.6 - 6.0	Moderately acid	0.6
6.1 - 6.5	Slightly acid	0.8
6.6 - 7.3	Neutral	1.0
7.4 - 7.8	Slightly alkaline	0.8
7.9 - 8.4	Moderately alkaline	0.6
8.5 - 9.0	Strongly alkaline	0.4
9.1 - 11.0	Very strongly alkaline	0.2

Hardpan

Each soil description was checked to see if the presence of a hardpan was reported. A hardpan can impede the percolation of water below a recharge pond, limiting the suitability of a potential project site. If a hardpan was present, a parameter score of 0 was assigned. If there was no hardpan occurrence, then a value of 1 was assigned.

The raw soil data is available in Appendix B. As can be expected when gathering data from diverse sources, not all soil surveys reported the same soil parameters. When a particular piece of data, such as permeability, was not available for a soil type, we attempted to locate the value in a soil survey for an adjacent county before invoking any other approximation method. We will point out where we were forced to approximate a soil parameter in later sections dealing with specific potential groundwater banking sites.

3.3.2 Soils Sub-Index Weighting Factors

Once the parameter scores were developed for each of the soil types at the potential groundwater banking sites, a weighted average parameter score was calculated based on the area of each soil type overlying potential project sites. The area data is available in Appendix C. This produced a score for each site for each of the four soil parameters. The soils sub-index was calculated by applying the weighting factors shown in the following equation:

$$\boxed{\text{Soils Sub-Index} = (\text{Thickness})*\ (3*[\text{Permeability}] + [\text{pH}] - 2*[1 - \text{Hardpan}])} \tag{3.5}$$

In Equation 3.5, permeability was weighted by a factor of 3 and hardpan by a factor of 2 to stress the importance of these components on the ability of water to percolate below recharge basins. Since potentially constraining soil parameters are subtracted in Equation 3.5, it is possible to arrive at negative sub-index values. Once again, another individual interested in groundwater banking could apply a different set of weighting factors in the spreadsheet developed for this project.

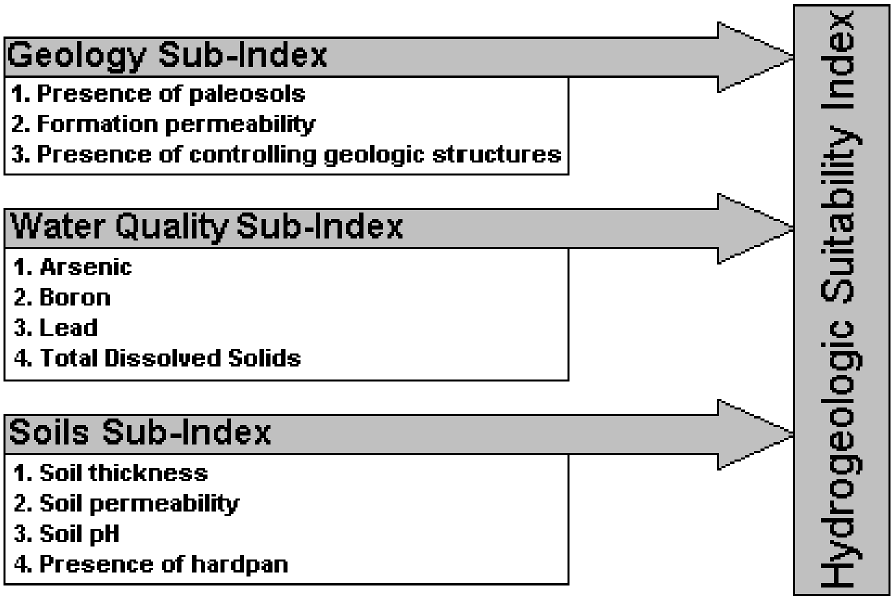
3.4 Application of the Core Hydrogeologic Suitability Index

The sub-indices presented in the previous sections constitute the core of the Hydrogeologic Suitability Index that will be applied to potential groundwater banking sites in both the Sacramento and San Joaquin Valleys. A separate sub-index based on the temporal evolution of the elevation of the water table is applied only in the San Joaquin Valley. Details of this sub-index are presented in Section 5.0 dealing with the application of the index in that region.

4.0 Application of the Hydrogeologic Suitability Index in the Sacramento Valley

As mentioned previously, differences in the hydrologic conditions between the Sacramento and San Joaquin Valleys prompted our decision to apply the Hydrogeologic Suitability Index separately in the two regions. In the Sacramento Valley, a core index that includes sub-indices related to geology, groundwater quality and soils has been applied. Figure 4.0.1 provides a summary flow chart of the information used to develop each of the sub-indices and the overall Hydrogeologic Suitability Index. Descriptions of each of the parameters presented in Figure 4.0.1 are given in Section 3.0, along with a proposed methodology for assigning parameter scores. The following sections present the data used to calculate the sub-indices for each of the potential Sacramento Valley groundwater banking sites shown in Figure 2.0.1.

Figure 4.0.1: Flow Chart of Parameters Analyzed in the Development of Relevant Sub-Indices and the Overall Hydrogeologic Suitability Index in the Sacramento Valley



4.1 Sacramento Valley Geology Sub-Index

In Section 3.1.1, the geology sub-index parameters were discussed. These parameters are permeability, the presence of paleosols, and the presence of any controlling geologic structures. The methodology used to create a weighted average of parameter scores based on the thickness of the formations encountered at a given site was also presented in Equation 3.2. The influence of formation thickness is a particularly important issue in the Sacramento Valley because although there is a tendency to think of Sacramento Valley groundwater in terms of a homogeneous underground reservoir that fluctuates gradually with wet and dry cycles, the reality is more complex. While much of the Sacramento Valley groundwater basin is interconnected, aquifer structure is far from uniform (DWR, 1998). Considering the properties of only the uppermost formation would miss many important controls that this complex geology could exert on the groundwater banking operations using recharge ponds. The vertical sequence of formations must be taken into consideration along with their horizontal extent.

Geology Sub-Index Equation Key

Eq. 3.1: Formation Score = 2*(Permeability) + 0.5*(Paleosols) + (Geological Structure)
Eq. 3.2: Geology Sub-Index = Σ (Formation Score $_A$*Formation Thickness $_A$)

4.1.1 Results of the Sacramento Valley Geology Sub-Index

Table 4.1.1 contains a list of the geologic formations encountered below the potential groundwater banking sites identified for the Sacramento Valley. The table also includes the parameter scores assigned to the formations in terms of permeability, paleosols and geologic structures. The formation scores, as calculated using Equation 3.1, are listed in the Rank column. These scores are then normalized between 0 and 1 according to their relative position between the formation with the highest (Stony Creek Fan with a score of 32) and lowest (Mehrten, Flood Basin Deposits and South Fork Gravels with scores of 14) ranks. The normalized ranks are found in the % column.

Table 4.1.1: Scores for Formations Found in the Sacramento Valley

Weighting Coefficient	0.5	2	1		
Formation	**Paleosols**	**Permeability**	**Geo. Strct.**	**Rank**	**%**
Stony Creek Fan	10	8.5	10	32	1.00
Putah Plain	10	6	10	27	0.72
Tuscan	0	10	5	25	0.61
Arbuckle Fan	10	7	5	24	0.56
Chico Fan	10	7	5	24	0.56
Laguna	10	5	5	20	0.33
Victor	0	6	5	17	0.17
Tehama	10	3	5	16	0.11
Fanglomerate	10	2.5	5	15	0.06
Mehrten	10	2	5	14	0.00
Flood Basin	10	2	5	14	0.00
South Fork Gravels	10	2	5	14	0.00

Having ranked the various formations encountered in the Sacramento Valley, we examined the vertical stratification of these units below each of the potential groundwater banking sites located in the Sacramento Valley (as shown in Figure 2.0.1). The formations encountered, which have been color coded according to their formation scores, are shown in Figure 4.1.1. If a program of groundwater banking is based on the use of recharge ponds, then the sequence of formations down from the ground surface at a potential site is critical. If a formation that is poorly suited to groundwater banking overlies one with attractive geologic properties, the opportunity for groundwater banking using recharge ponds is constrained by the poorly suited upper formation. In applying Equation 3.2, the formation sequence was taken into consideration.

Table 4.1.2 contains a list of the potential groundwater banking sites in the Sacramento Valley with the sequence of formations encountered down to a depth of 500 feet listed to the right, along with the formation score and local thickness. The geology sub-index is calculated by applying Equation 3.2 down to and including the first formation that overlies one with a higher score. For example, at the American Basin site, where the Victor Formation with a score of 0.17 overlies the Laguna Formation with a score of 0.33, only the properties and thickness of the overlying Victor Formation are considered in calculating the geology sub-index. This calculation has been carried out based on three assumed operational depths for the proposed groundwater banking projects: 100 ft., 300 ft. and 500 ft.

Figures 4.1.2 through 4.1.4 graphically present the rank associated with each potential site in terms of the geology sub-index under different assumptions regarding operational depth.

Figure 4.1.1: Vertical Stratification of Formations Encountered at Potential Groundwater Banking Sites in the Sacramento Valley

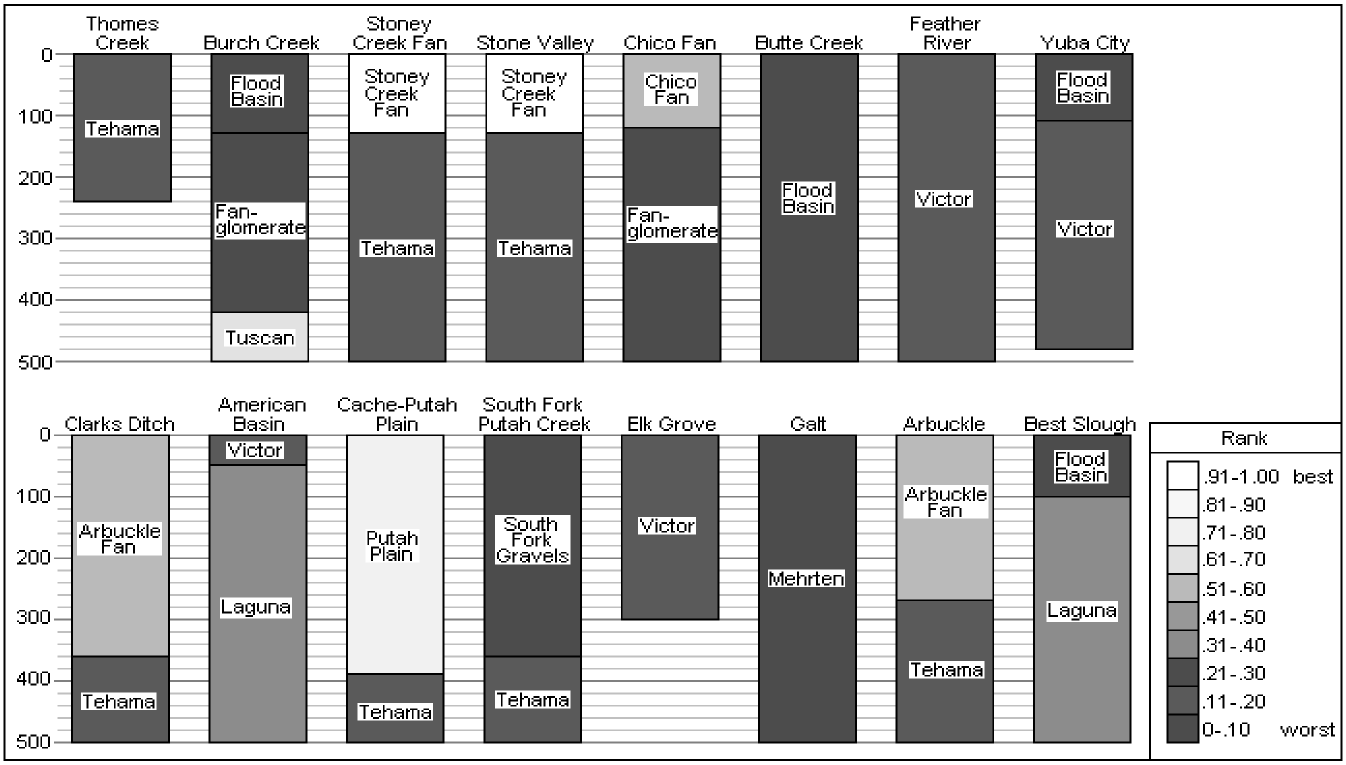


Table 4.1.2: Geology Sub-Index Values Calculated for Potential Groundwater Banking Sites in the Sacramento Valley

	Formation 1			Formation 2			Formation 1			Operational Depth					
										500 ft		300 ft		100 ft	
Site	Formation	Score	Thickness	Formation	Score	Thickness	Formation	Score	Thickness	Score	Normal	Score	Normal	Score	Normal
Cache-Putah Plain	Putah Plain	0.72	390	Tehama	0.11	110				293.9	1.00	216.7	1.00	72.2	0.72
Clarks Ditch	Arbuckle Fan	0.56	360	Tehama	0.11	140				215.6	0.73	166.7	0.77	55.6	0.56
Arbuckle	Arbuckle Fan	0.56	260	Tehama	0.11	240				171.1	0.58	148.9	0.69	55.6	0.56
Stoney Creek Fan	Stony Creek Fan	1.00	130	Tehama	0.11	370				171.1	0.58	148.9	0.69	100.0	1.00
Stone Valley	Stony Creek Fan	1.00	130	Tehama	0.11	370				171.1	0.58	148.9	0.69	100.0	1.00
Chico Fan	Chico Fan	0.56	120	Fanglomerate	0.06	380				87.8	0.30	76.7	0.35	55.6	0.56
Feather River	Victor	0.17	500							83.3	0.28	50.0	0.23	16.7	0.17
Elk Grove	Victor	0.17	300							50.0	0.17	50.0	0.23	16.7	0.17
Thomes Creek	Tehama	0.11	240							26.7	0.09	26.7	0.12	11.1	0.11
American Basin	Victor	0.17	30	Laguna	0.33	470				5.0	0.02	5.0	0.02	5.0	0.05
Best Slough	Flood Basin	0.00	100	Laguna	0.33	400				0.0	0.00	0.0	0.00	0.0	0.00
Burch Creek	Flood Basin	0.00	130	Fanglomerate	0.06	280	Tuscan	0.61	90	0.0	0.00	0.0	0.00	0.0	0.00
Yuba City	Flood Basin	0.00	100	Victor	0.17	400				0.0	0.00	0.0	0.00	0.0	0.00
S. Fork Putah Creek	S. Fork Gravels	0.00	360	Tehama	0.11	140				0.0	0.00	0.0	0.00	0.0	0.00
Butte Creek	Flood Basin	0.00	500							0.0	0.00	0.0	0.00	0.0	0.00
Galt	Mehrten	0.00	500							0.0	0.00	0.0	0.00	0.0	0.00

Figure 4.1.2: Sacramento Valley Geology Sub-Index Values Assuming an Operational Depth of 500 Feet

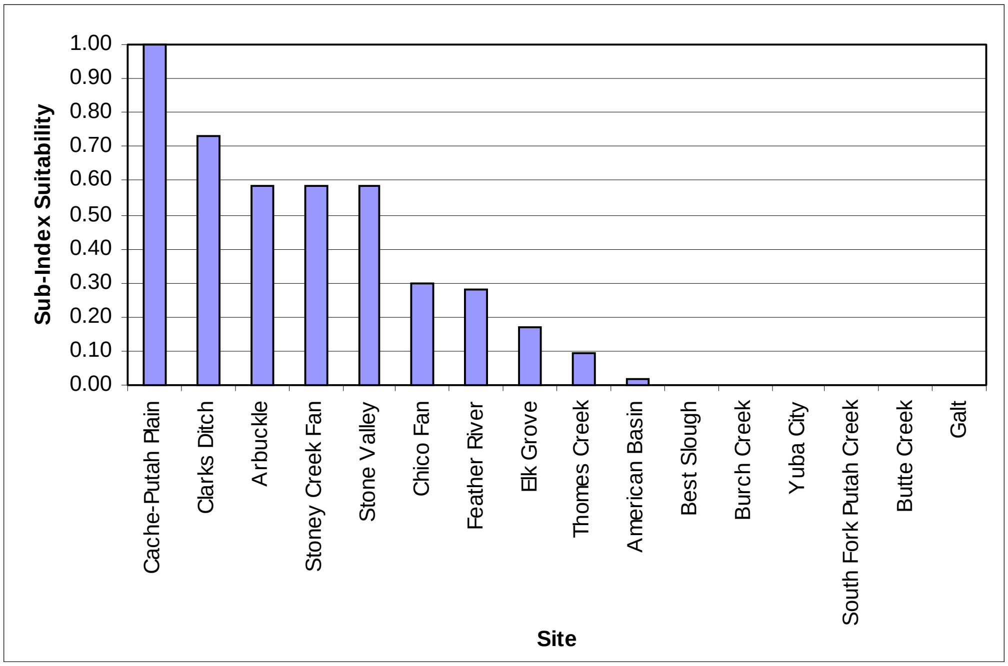


Figure 4.1.3: Sacramento Valley Geology Sub-Index Values Assuming an Operational Depth of 300 Feet

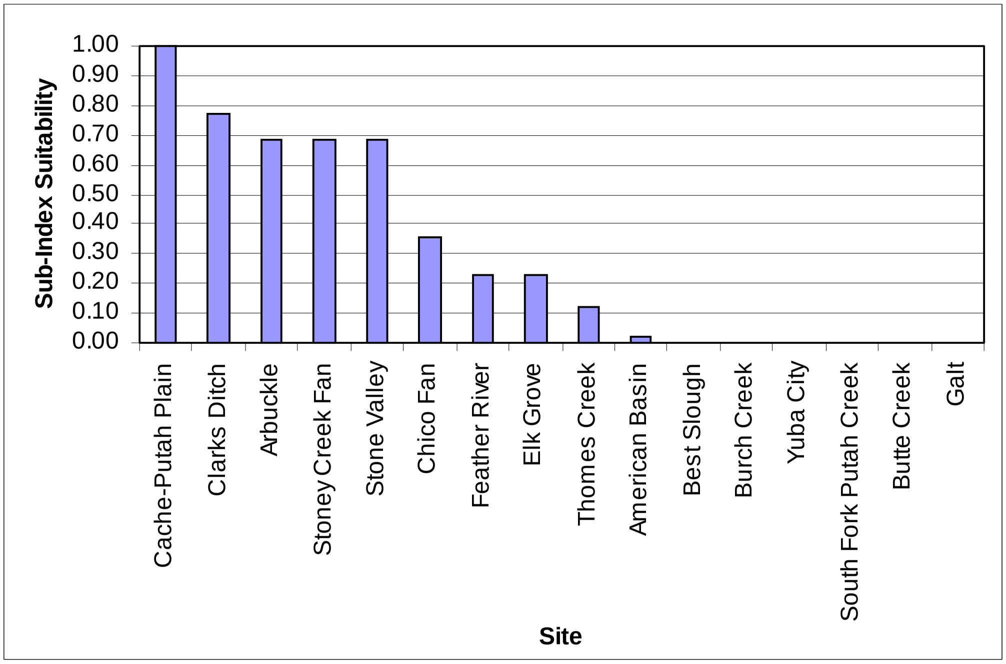
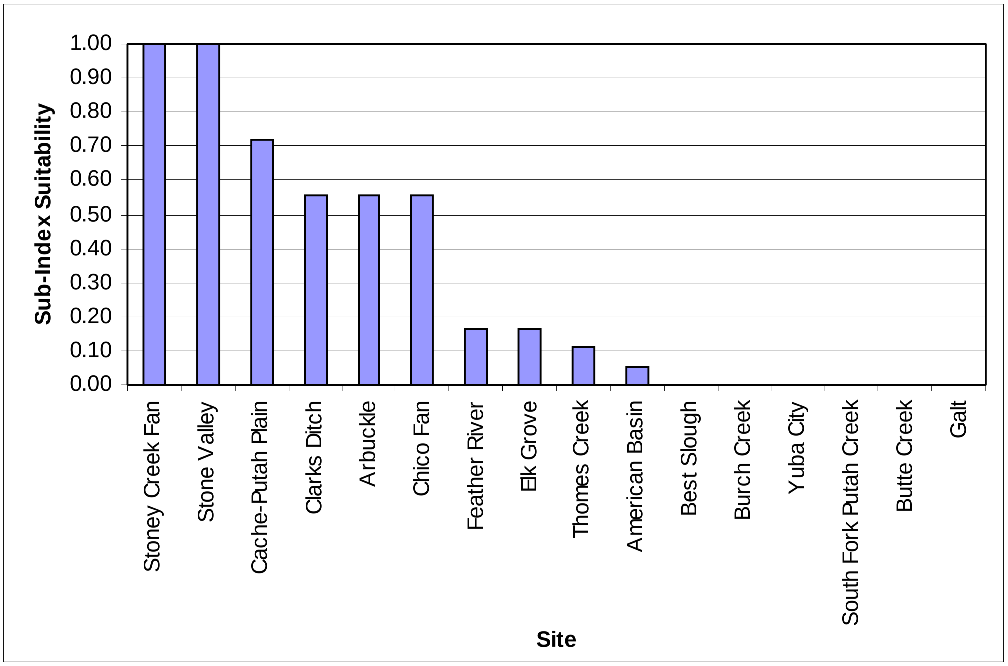
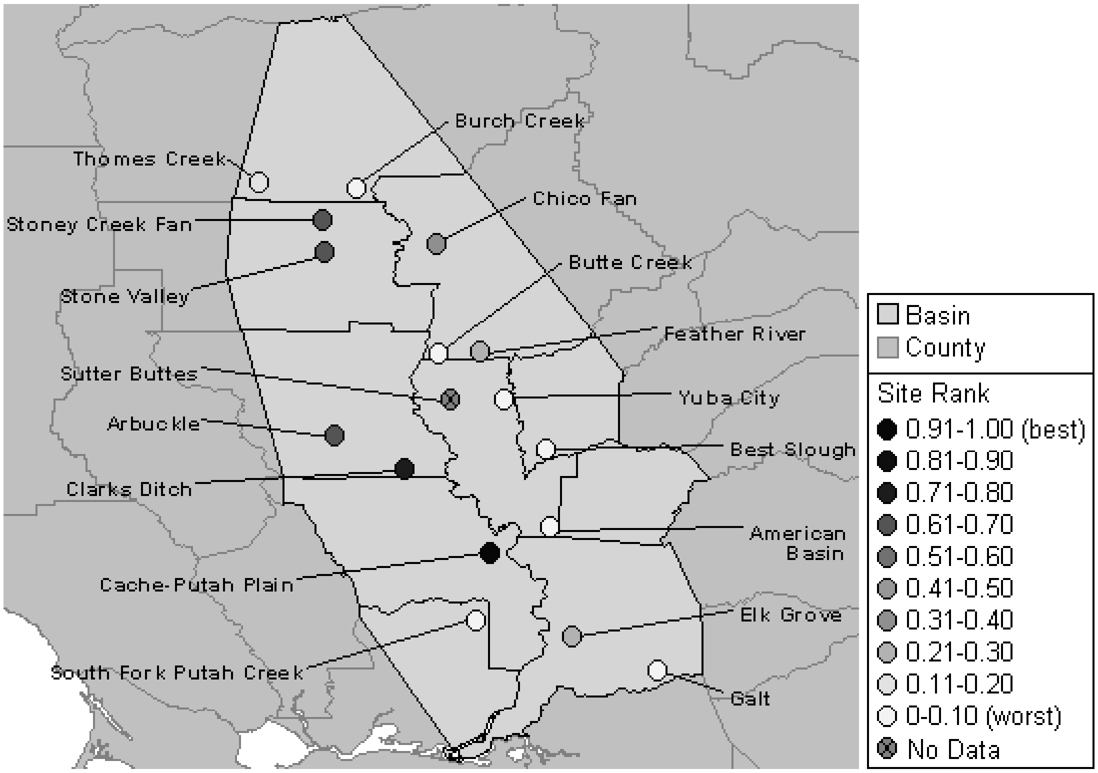


Figure 4.1.4: Sacramento Valley Geology Sub-Index Values Assuming an Operational Depth of 100 Feet



In calculating the overall Hydrogeologic Suitability Index for sites in the Sacramento Valley, geology sub-index values based on an assumed operational depth of 300 ft. are employed. Figure 4.1.5 displays the site comparison of the potential groundwater banking sites with respect to the 300 ft. depth rank.

Figure 4.1.5: Spatial Distribution of 300 Ft. Depth Geology Sub-Index Values Across Potential Groundwater Banking Sites in the Sacramento Valley



4.1.2 Comments on the Geology Sub-Index

Several interesting observations emerge from the results of the geology sub-index. First, sites in the western Sacramento Valley (e.g., Stony Creek Fan, Arbuckle Fan, Cache-Putah Plain) provide excellent geologic settings for groundwater banking. This is an important discovery because the aquifers underlying these sites are generally full. As such, groundwater banking would require some level of enhanced groundwater pumping in order to create the space required for storing banked groundwater—a management sequence that raises legitimate concerns on the part of overlying groundwater users. The relative superiority of these sites in terms of the geology, however, suggest that it may be worth the effort to design the legal and institutional arrangements needed to make these sorts of projects viable.

Sites located in the central and eastern portions of the Sacramento Valley generally fare less well in terms of the geology sub-index. This is due to the prevalence of flood basin deposits and the Victor Formation in the upper portion of the stratigraphic column below these sites. While more promising formations often lie below these units, access to them via recharge basins will be constrained by the less suitable overlying formations. These are areas where groundwater banking via injection wells or *in lieu* arrangements may be the preferred alternative.

4.2 Sacramento Valley Water Quality Sub-Index

As mentioned in Section 3.2, the water quality sub-index was based on the reported concentrations in groundwater of four parameters: arsenic, boron, lead and total dissolved solids.

Water Quality Sub-Index Equation Key

Eq. 3.3: Water Quality Score = [As Score] + [B Score] + [Pb Score] + [TDS Score]
Eq. 3.4: Water Quality Sub-Index = 1.5*[Basin Score] + [Site Score]

4.2.1 Results of the Sacramento Valley Water Quality Sub-Index

For each of the basins in the Sacramento Valley (see Figure 2.0.1), the average of all observations was used to assign a parameter score according to Table 3.2.1. The total water quality scores (in the Rank column), calculated using Equation 3.3, and normalized values between 0 and 1 (in the % column), are shown in Table 4.2.1.

Table 4.2.1: Water Quality Scores for Basins in the Sacramento Valley

Weighting Coefficient	1	1	1	1		
Basin Name	**As**	**B**	**Pb**	**TDS**	**Rank**	**%**
Tehama	10	9	10	8	37	1.00
Yuba	9	10	10	8	37	1.00
Butte	9	10	9	8	36	0.86
Placer	9	8	10	8	35	0.71
Glenn	8	10	9	7	34	0.57
Sutter	7	10	9	7	33	0.43
Colusa	9	9	8	6	32	0.29
Solano	9	8	10	5	32	0.29
Sacramento	7	10	8	8	31	0.14
Yolo	9	5	10	6	30	0.00

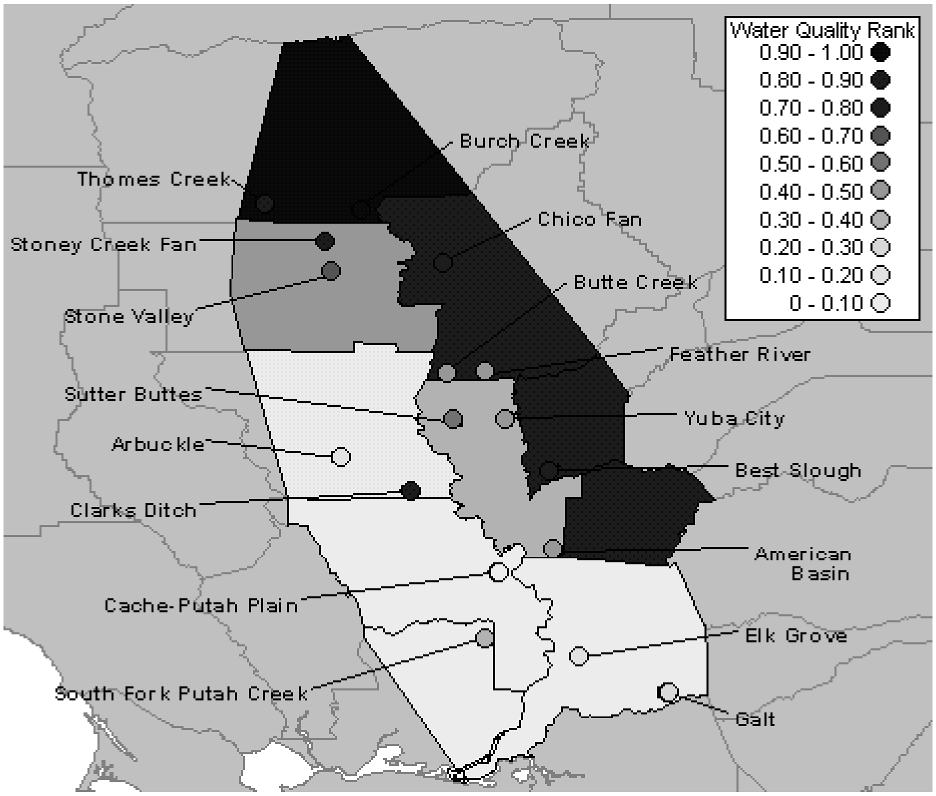
Based on contour maps developed from the available data in each basin, estimated concentrations, parameter scores and normalized values between 0 and 1 were developed for each of the potential Sacramento Valley groundwater banking sites (Table 4.2.2).

The information in both Tables 4.2.1 and 4.2.2 is displayed spatially in Figure 4.2.1.

Table 4.2.2: Water Quality Scores for Sites in the Sacramento Valley

Weighting Coefficient	1	1	1	1		
Site Name	**As**	**B**	**Pb**	**TDS**	**Rank**	**%**
Burch Creek	10	10	10	9	39.00	1.00
Clarks Ditch	10	10	10	8	38.00	0.89
Stoney Creek Fan	10	10	10	8	38.00	0.89
Thomes Creek	10	10	10	8	38.00	0.89
Best Slough	9	10	10	8	37.00	0.78
Chico Fan	10	10	9	8	37.00	0.78
Stone Valley	9	10	9	8	36.00	0.67
Sutter Buttes	6	10	10	9	35.00	0.56
American Basin	7	10	9	8	34.00	0.44
Butte Creek	7	10	9	8	34.00	0.44
Feather River	7	10	10	7	34.00	0.44
Yuba City	6	10	10	8	34.00	0.44
South Fork Putah Creek	8	8	10	7	33.00	0.33
Galt	6	10	8	8	32.00	0.22
Arbuckle	9	6	8	8	31.00	0.11
Elk Grove	5	10	9	7	31.00	0.11
Cache-Putah Plain	8	5	10	7	30.00	0.00

Figure 4.2.1: Spatial Distribution of Basin and Site Water Quality Scores



Based on the water quality scores presented in Tables 4.2.1 and 4.2.2, the water quality sub-index for potential groundwater banking sites in the Sacramento Valley was calculated according to Equation 3.4. These scores were normalized between 0 (corresponding with the poorest groundwater quality at the Cache Putah Plain site) and 1 (corresponding with the best groundwater quality observed at the Burch Creek site). The results are shown in Table 4.2.3.

Table 4.2.3: Water Quality Sub-Index Values for Potential Groundwater Banking Sites in the Sacramento Valley

Weighting Coefficient		1.5	1		
Site Name	**Basin**	**Basin Wide**	**Site Specific**	**Rank**	**%**
Thomes Creek	Tehama	1.00	0.89	2.39	0.96
Burch Creek	Tehama	1.00	1.00	2.50	1.00
Stoney Creek Fan	Glenn	0.57	0.89	1.75	0.70
Stone Valley	Glenn	0.57	0.67	1.52	0.61
Elk Grove	Sacramento	0.14	0.11	0.33	0.13
Butte Creek	Butte	0.86	0.44	1.73	0.69
Feather River	Butte	0.86	0.44	1.73	0.69
Chico Fan	Butte	0.86	0.78	2.06	0.83
American Basin	Sutter	0.43	0.44	1.09	0.43
Galt	Sacramento	0.14	0.22	0.44	0.17
Arbuckle	Colusa	0.29	0.11	0.54	0.22
Sutter Buttes	Sutter	0.43	0.56	1.20	0.48
Yuba City	Sutter	0.43	0.44	1.09	0.43
Clarks Ditch	Colusa	0.29	0.89	1.32	0.53
Cache-Putah Plain	Yolo	0.00	0.00	0.00	0.00
South Fork Putah Creek	Solano	0.29	0.33	0.76	0.30
Best Slough	Yuba	1.00	0.78	2.28	0.91

Figures 4.2.2 and 4.2.3 present the value of the water quality sub-index for potential banking sites in the Sacramento Valley derived from available data in terms of relative rank and spatial distribution, respectively.

4.2.2 Comments on the Water Quality Sub-Index

It is worth noting that the water quality of all sites in the Sacramento Valley is fairly good. However, boron does reach the recommended maximum level for boron-sensitive crops in the Cache-Putah Plain site and is also rather high in the Arbuckle region. There appears to be an area of increased arsenic levels in the northeast part of the valley, though these levels are still below the recommended levels and far below toxicity. Lead levels are very low in the Sacramento Valley, though anything over zero is considered too much by EPA standards. TDS is also very low, though levels seem to rise toward the south. While the Hydrogeologic Suitability Index is applied separately to sites in the Sacramento and San Joaquin Valleys, the relatively good quality of groundwater in the Sacramento Valley suggests that sites in this region are worthy of consideration despite the fact that little or no aquifer storage space currently exists in this region.

Figure 4.2.2: Water Quality Sub-Index Ranking for Potential Groundwater Banking Sites in the Sacramento Valley

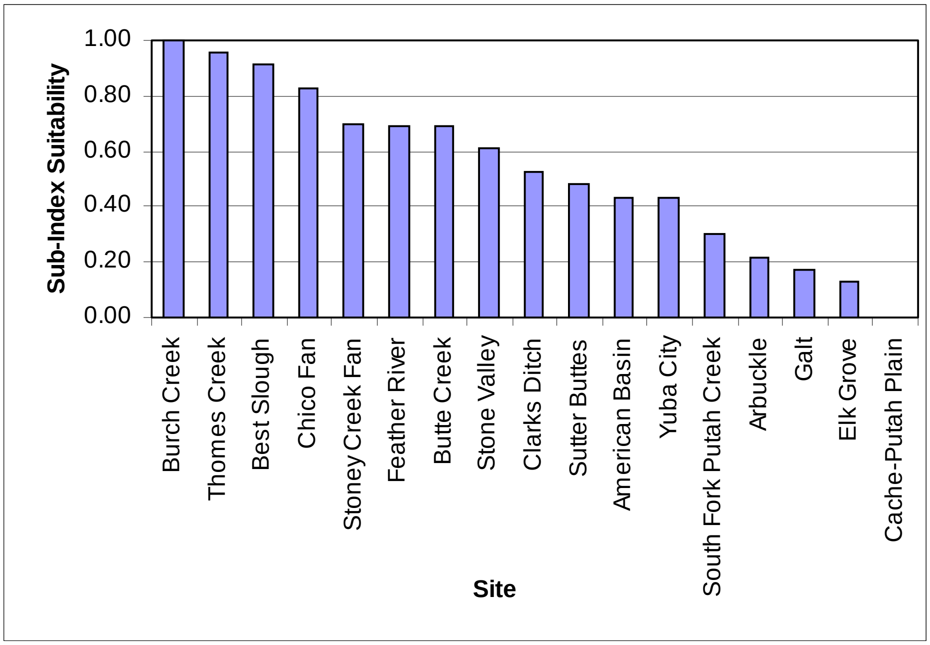
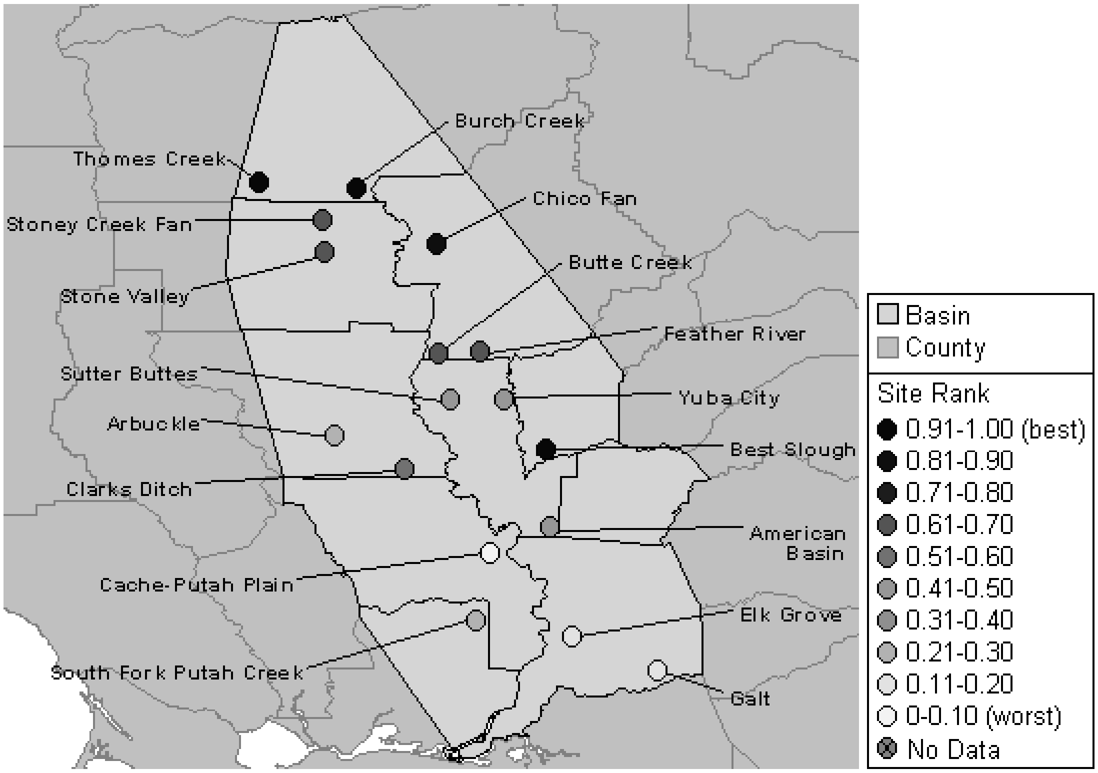


Figure 4.2.3: Spatial Distribution of Water Quality Sub-Index Values Across Potential Groundwater Banking Sites in the Sacramento Valley



4.3 Sacramento Valley Soils Sub-Index

The soils sub-index was calculated as described in Section 3.3. The soil types under a site were identified, evaluated and scored based on the four soil parameters: thickness, pH, permeability and hardpan. The soils sub-index was not calculated directly for several of the sites in the Sacramento Valley owing to a lack of an available soil survey. These sites are listed in Table 4.3.1. For these sites, treatment of the soil sub-index in the calculation of the overall Hydrogeologic Suitability Index is discussed in Section 4.4.

Table 4.3.1: Soil Sites Lacking Available Soil Surveys

Site	Basin
Chico Fan	Butte
Butte Creek	Butte
Feather River	Butte
Arbuckle	Colusa
Clarks Ditch	Colusa

4.3.1 Results for the Sacramento Valley Soils Sub-Index

The soils sub-index values that were calculated using Equation 3.5 are shown in Table 4.3.2, in the column entitled "Rank." Normalized values between 1 (corresponding to the Sutter Buttes site) and 0 (corresponding with the Elk Grove site) are listed in the % column. These results are displayed graphically in terms of their rank and their spatial distribution in Figures 4.3.1 and 4.3.2, respectively.

Soil Sub-Index Equation Key

Eq. 3.5: Soils Sub-Index = (Thickness) [3(Permeability) + (pH)– 2(1 – Hardpan)]

Table 4.3.2: Soils Sub-Index Values for Potential Groundwater Banking Sites in the Sacramento Valley

Weighting Coefficient	1	3	2	1		
Site	**Thickness**	**Permeability**	**Hardpan**	**pH**	**Rank**	**%**
Thomes Creek	0.70	0.13	1.00	0.65	1.75	0.78
Stoney Creek Fan	0.75	0.14	0.86	0.71	1.58	0.71
Stone Valley	0.73	0.13	1.00	0.81	1.92	0.85
Sutter Buttes	0.41	0.33	1.00	0.90	2.32	1.00
Galt	0.78	0.08	0.95	0.51	1.41	0.64
Cache-Putah Plain	0.40	0.22	0.96	0.65	1.64	0.73
Yuba City	0.54	0.07	1.00	0.78	1.53	0.69
South Fork Putah Creek	0.66	0.01	1.00	0.65	1.34	0.62
American Basin	0.75	0.08	0.16	0.80	0.09	0.12
Best Slough	0.50	0.06	0.31	0.77	0.07	0.11
Elk Grove	0.75	0.08	0.00	0.79	-0.21	0.07
Burch Creek	0.60	0.11	0.77	0.65	1.11	0.52

To estimate the soils sub-index for the sites lacking the soil survey data needed for sub-index Equation 3.5, the agricultural crops grown on these sites were identified. Two types of crops were identified on the five sites in Table 4.3.1. The Butte Creek site cultivated rice, which requires clayey soils with extremely low permeabilities. These types of soils are not appropriate for groundwater banking, as discussed in Section 3.3.1, so Butte Creek was given a soils sub-index value of zero. The other four sites from Table 4.3.1 were mainly composed of orchards, which indicate a more average loamy soil with moderate permeability. The score for these sites was calculated by averaging the sub-index scores shown in Table 4.3.2, arriving at an estimated score of 0.56. Figure 4.3.1 shows these estimated values in relation to the values displayed in Table 4.3.2.

Figure 4.3.1: Soils Sub-Index Ranking for Potential Groundwater Banking Sites in the Sacramento Valley

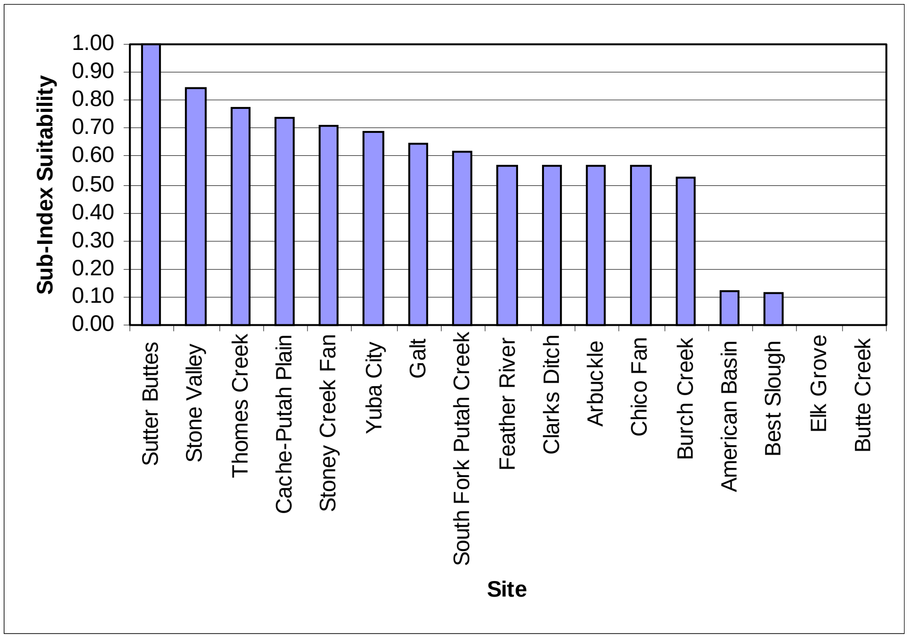
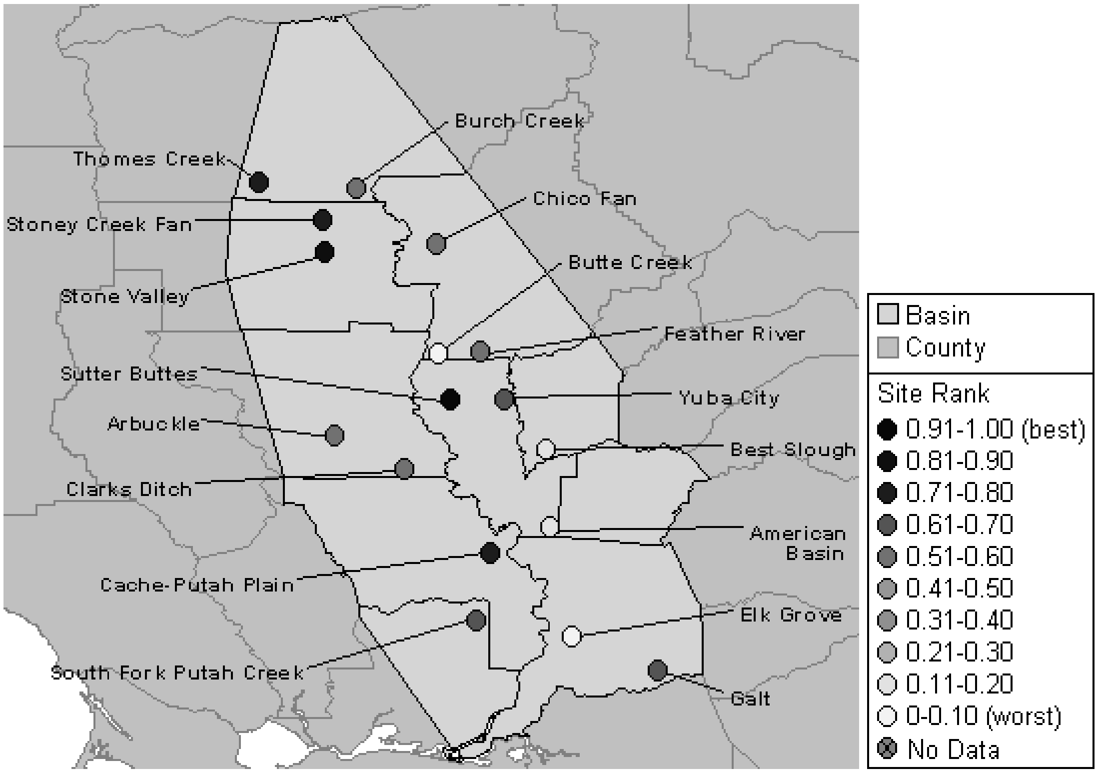


Figure 4.3.2: Spatial Distribution of Soils Sub-Index Values Across Potential Groundwater Banking Sites in the Sacramento Valley



4.3.2 Comments on the Soils Sub-Index

Areas with highly desirable soil characteristics are found primarily in the northern and western regions of the valley. Unfortunately, actual data were not available for much of Butte and Colusa Counties and had to be estimated. The Excel project that accompanies this report would be an appropriate place to input more specific soil data for these sites, should this information become available.

4.4 Sacramento Valley Hydrogeologic Suitability Index

Having evaluated the sites in terms of three relevant sub-indices, we combined the sub-indices to derive the overall Hydrogeologic Suitability Index. The overall index of suitability in the Rank column in Table 4.4.1 was arrived at by applying Equation 4.1.

$$\boxed{\text{Hydrogeologic Suitability Index} = 2*(\text{Geology}) + 2*(\text{Water Quality}) + (\text{Soils})} \tag{4.1}$$

In this analysis, the geology and water quality sub-indices are weighted by 2 to stress their importance. The characteristics of the underlying formations determine whether water can be stored in an aquifer, and the water quality of the area is crucial if stored water is to be used for agriculture and urban uses. Soils are not weighted as high because problematic soils can be removed as part of project construction, although this would increase the overall cost of the project.

4.4.1 Results for the Sacramento Valley Hydrogeologic Suitability Index

Table 4.4.1 shows the overall Hydrogeologic Suitability Index. Values were normalized between 1 (corresponding to the most suitable site at Stoney Creek Fan) and 0 (corresponding with Elk Grove) in the % column.

The overall Hydrogeologic Suitability Index values for sites in the Sacramento Valley are displayed graphically in terms of their rank and their spatial distribution in Figures 4.4.1 and 4.4.2, respectively.

Table 4.4.1: Sacramento Valley Hydrogeologic Suitability Index

Weighting Coefficient	2	2	1		
Site	**Geology**	**Water Quality**	**Soils**	**Rank**	**%**
Stoney Creek Fan	0.69	0.70	0.71	3.48	1.00
Thomes Creek	0.12	0.96	0.78	2.93	0.80
Stone Valley	0.69	0.61	0.85	3.28	0.93
Chico Fan	0.35	0.83	0.56*	2.92	0.80
Arbuckle	0.69	0.22	0.56*	2.37	0.60
Cache-Putah Plain	1.00	0.00	0.73	2.73	0.73
Feather River	0.23	0.69	0.56*	2.41	0.61
Galt	0.00	0.17	0.64	0.99	0.10
Elk Grove	0.23	0.13	0.00	0.72	0.00
Clarks Ditch	0.77	0.53	0.56*	3.16	0.88
American Basin	0.02	0.43	0.12	1.03	0.11
Sutter Buttes	0.30*	0.48	1.00	2.56	0.67
Yuba City	0.00	0.43	0.69	1.56	0.30
Butte Creek	0.00	0.69	0.00*	1.38	0.24
South Fork Putah Creek	0.00	0.30	0.62	1.23	0.18
Best Slough	0.00	0.91	0.11	1.94	0.44
Burch Creek	0.00	1.00	0.52	2.52	0.65

Figure 4.4.1: Hydrogeologic Suitability Index Ranking for Potential Groundwater Banking Sites in the Sacramento Valley

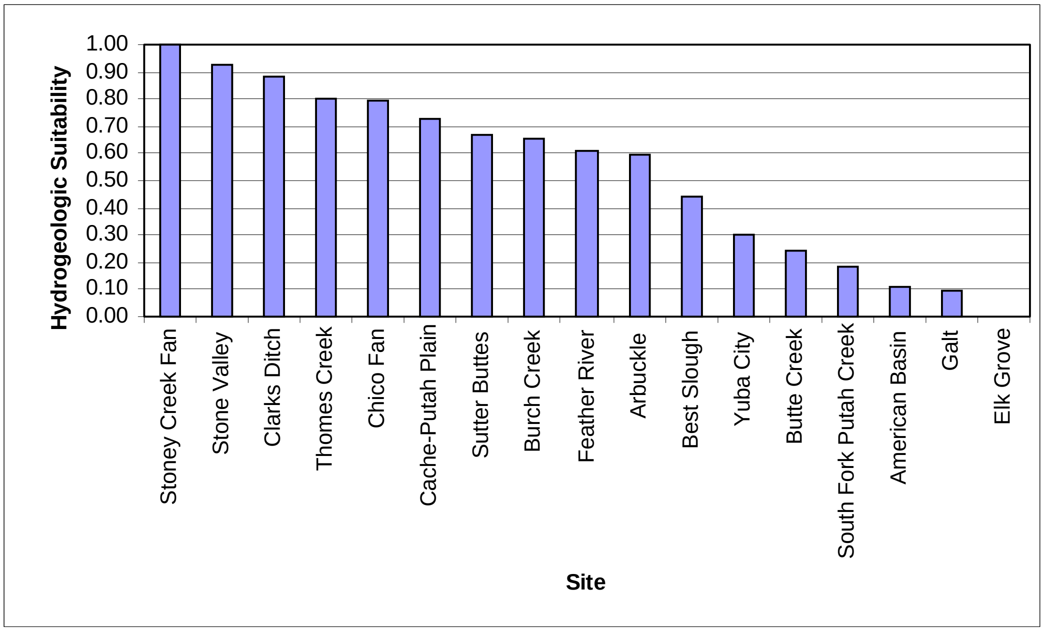
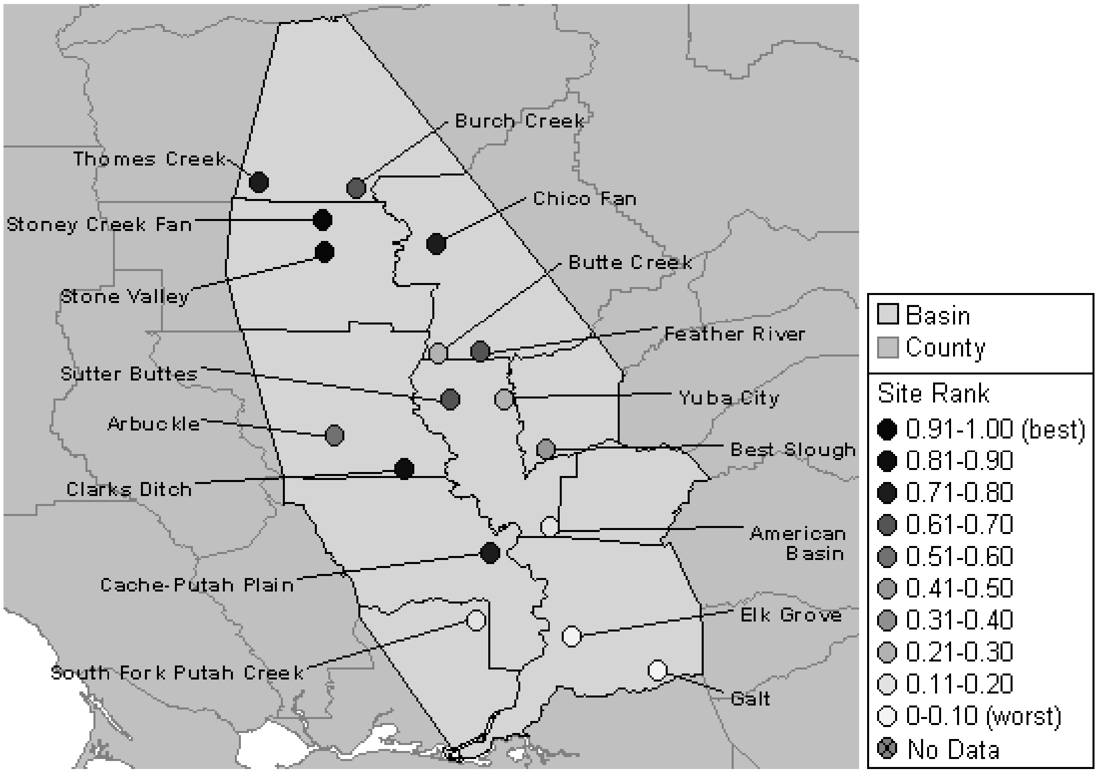


Figure 4.4.2: Spatial Distribution of the Hydrogeologic Suitability Index Values Across Potential Groundwater Banking Sites in the Sacramento Valley



4.4.2 Comments on the Sacramento Valley Hydrogeologic Suitability Index

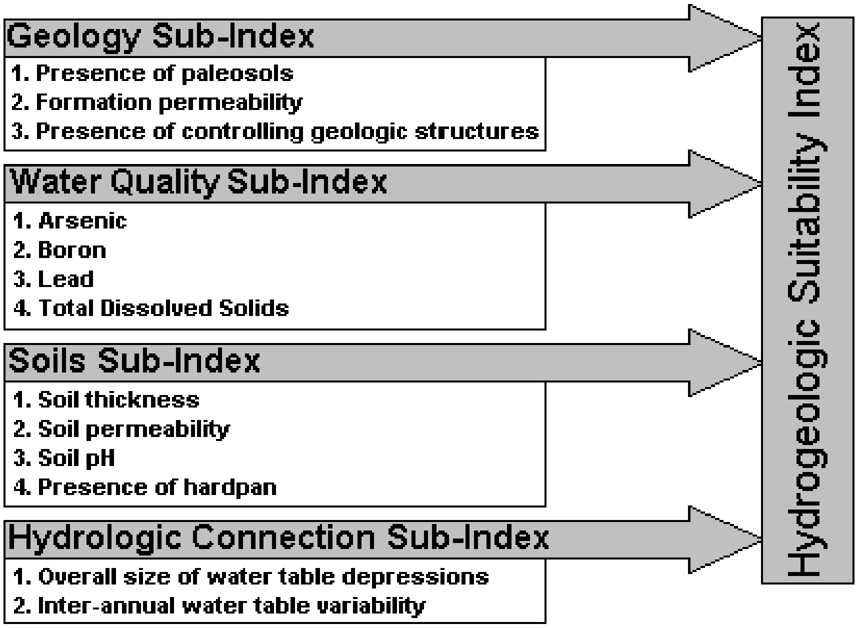
When all of the relevant sub-index values are taken into consideration, there appears to be a trend from the most suitable sites in the northern portion of the Sacramento Valley toward generally less suitable sites in the south. This has important implications in terms of integrating these sites into the state's surface water distribution network, as only Shasta Reservoir physically commands the most northern sites. While Shasta is a large facility, operational constraints associated with temperature control objectives may limit the ability to use Shasta as a direct source for groundwater banking. This suggests that a program of coordinated release from all of the Sacramento Valley reservoirs may be needed to "back" water up into Shasta Reservoir for eventual transfer to northern banking sites.

It should be pointed out that the ranking depicted in Figure 4.4.1 is purely a function of the numerical values assigned to each of the components and the weighting coefficients shown in Equation 4.1. It is possible that others interested in groundwater banking in the Central Valley would apply different component values and weighting coefficients. In order to allow for further exploration of geology, groundwater quality and soils on the suitability of potential groundwater banking sites in the Sacramento Valley, the information used to generate the ranking in Table 4.4.1 has been made available in the spreadsheet developed as part of this effort. In this spreadsheet, any of the values or weighting coefficients applied to the sub-indices may be changed and the new results can be viewed in tables and graphs similar to those in Table 4.4.1 and Figure 4.4.1.

5.0 Application of the Hydrogeologic Suitability Index in the San Joaquin Valley

The second application of the Hydrogeologic Suitability Report is in the San Joaquin Valley. Potential groundwater banking sites in this region are shown in Figure 2.0.2. As in the Sacramento Valley, each of the sites is evaluated in terms of the core index that covers relevant geology, groundwater quality and soils characteristics. In the case of the San Joaquin Valley, however, the index has been expanded to include a sub-index related to observed fluctuations in the water table below potential banking sites. As mentioned in Section 1.0, portions of the San Joaquin Valley have been exposed to prolonged periods of groundwater overdraft, resulting in the creation of significant and persistent cones of depression. These features will likely serve as the locus of groundwater storage in the San Joaquin Valley. The hydrologic connection sub-index is designed to assess the degree to which water deposited by groundwater banking at potential sites will remain available for eventual recovery. Details of this sub-index are presented in Section 5.4. Figure 5.0.1 provides a summary flow chart of the information used to develop and apply the Hydrogeologic Suitability Index in the San Joaquin Valley.

Figure 5.0.1: Flow Chart of Parameters Analyzed in the Development of Relevant Sub-Indices and the Overall Hydrogeologic Suitability Index in the San Joaquin Valley



5.1 San Joaquin Valley Geology Sub-Index

Deep, undifferentiated lacustrian and alluvial deposits characterize San Joaquin Valley geology. This contrasts with the Sacramento Valley, where various formations of differing thickness are encountered with depth below numerous sites. As such, in the San Joaquin Valley it is not generally possible to construct stratigraphic columns similar to those found in Figure 4.1.1. In fact, we assume that the formations encountered at each potential banking site are sufficiently thick to span the entire operational depth of a potential groundwater bank. In this case, the thickness of the single formation encountered at each potential banking site is treated as a parameter in the geology sub-index rather than as a weighting factor applied to the other geologic parameters (as in Equation 3.2). This thickness parameter is scaled as shown below (Table 5.1.1) in the adaptation to the Parameter Weighting Factors Table (Table 3.1.1).

Geology Sub-Index Equation Key

Eq. 3.2: Geology Sub-Index $= \Sigma$ (Formation Score $_A$ *Formation Thickness $_A$)

Table 5.1.1: Parameter Weighting Factors Used to Calculate the Geology Sub-Index, Adapted to Include Thickness as a Parameter for the San Joaquin Valley Hydrogeologic Suitability Index

Component	**0**	**5**	**10**
Permeability	Impermeable	Moderately permeable	Highly permeable
Paleosols	Contains resistant paleosols	Contains some slightly resistant paleosols	No paleosols
Geologic Structure	Contains structural features that direct stored groundwater towards gaining streams	Contains no structural features	Contains structural features that isolate stored groundwater from gaining streams
Thickness	Less than 20 ft. thick	6 = 50 to 80 ft. 3 = 20 to 50 ft.	Equal to or exceeds 100 ft.

5.1.1 Results of the San Joaquin Geology Sub-Index

Parameter scores associated with the formations encountered at potential banking sites in the San Joaquin Valley are shown in Table 5.1.2. As in the Sacramento Valley, a score of 10 is associated with the most favorable characteristics of a given parameter. The geology sub-index (Table 5.1.3) was calculated from parameter scores based on Equation 5.1.

$$\text{Formation Score} = 2*(\text{Permeability}) + 0.5*(\text{Paleosols}) + (\text{Geological Structure}) + (\text{Thickness}) \qquad (5.1)$$

In this equation, permeability was assigned a weighting coefficient of 2 due to its importance in the suitability of a formation for groundwater banking. The existence of paleosols was assigned a weighting coefficient of 0.5 because the extent to which paleosols are described varies between

Table 5.1.2: Scores for Formations Found in the San Joaquin Valley

Weighting Coefficient	0.5	2	1	1	
Formation	**Paleosols**	**Permeability**	**Thickness**	**Geo. Setting**	**Rank**
Turlock Lake	4	6	10	5	29
Tulare Formation	10	7	5	5	29
Modesto	10	6	8	5	30
N.W. Kern Fan	10	5	8	10	33
Alluvial Fan Deposits	10	5	8	5	28

Table 5.1.3: Geology Sub-Index Values for Potential Groundwater Banking Sites in the San Joaquin Valley

Site ID	Basin	Geo Formation	Rank	%
Arvin-Edison	Kern	N.W. Kern Fan	33	1.00
Semitropic Ridge	Kern	N.W. Kern Fan	33	1.00
Berenda Creek	Madera	Modesto	30	0.40
Chowchilla Bypass	Chowchilla	Modesto	30	0.40
Dry Creek	Modesto	Modesto	30	0.40
Hetch Hetchy Aqueduct	Modesto	Modesto	30	0.40
Gravelly Ford	Madera	Modesto	30	0.40
Dutchman Creek	Merced	Modesto	30	0.40
Owens Creek	Merced	Modesto	30	0.40
Mormon Slough	Modesto	Modesto	30	0.40
Little Dry Creek	Madera	Turlock Lake	29	0.20
Montpellier	Turlock	Turlock Lake	29	0.20
Kern Water Bank	Kern	Tulare Formation	29	0.20
James Bypass	Kings	Alluvial Fan Deposits	28	0.00
White River	Tule	Alluvial Fan Deposits	28	0.00
Allensworth	Tule	Alluvial Fan Deposits	28	0.00

information sources, and when they are described they tend to be thin and discontinuous. The resulting score for each of the formations encountered at potential banking sites in the San Joaquin Valley is found in the Rank column in Table 5.1.2.

Having established the formation scores, an association was made between each potential groundwater banking site and the formation encountered at the target location. These associations are shown in Table 5.1.3, along with the normalized value of the geology sub-index site found in the % column. In this case a value of 1 corresponds with sites overlying the northwestern Kern fan deposits, as these were deemed to be most geologically suitable. A value of 0 is assigned to the alluvial fan deposits associated with the James Bypass, White River and Allensworth sites. The results of the geology sub-index are shown graphically for each of the potential banking sites in Figures 5.1.1 and 5.1.2. Respectively, these figures show the results in terms of the relative rank and the spatial distribution.

Figure 5.1.1: Geology Sub-Index Ranking for Potential Groundwater Banking Sites in the San Joaquin Valley

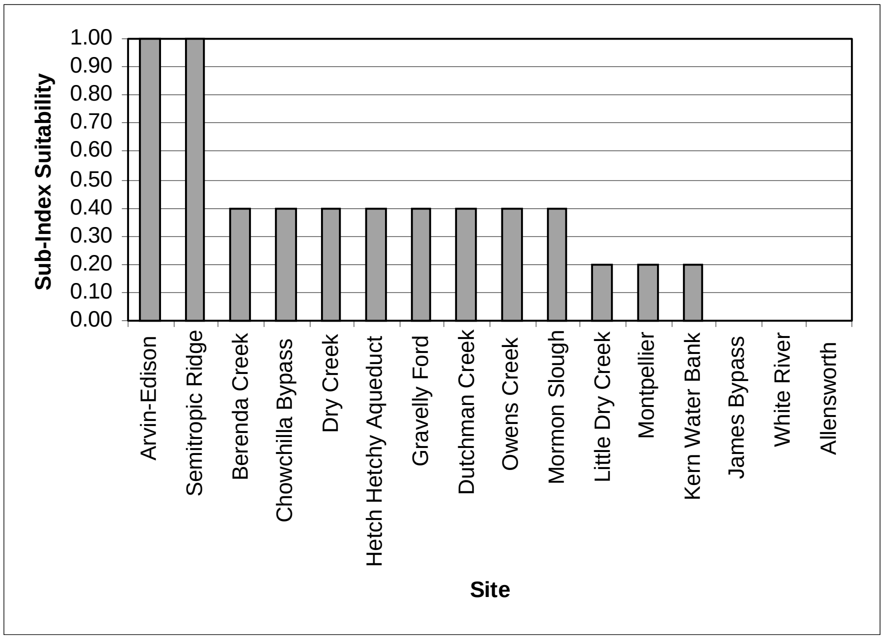
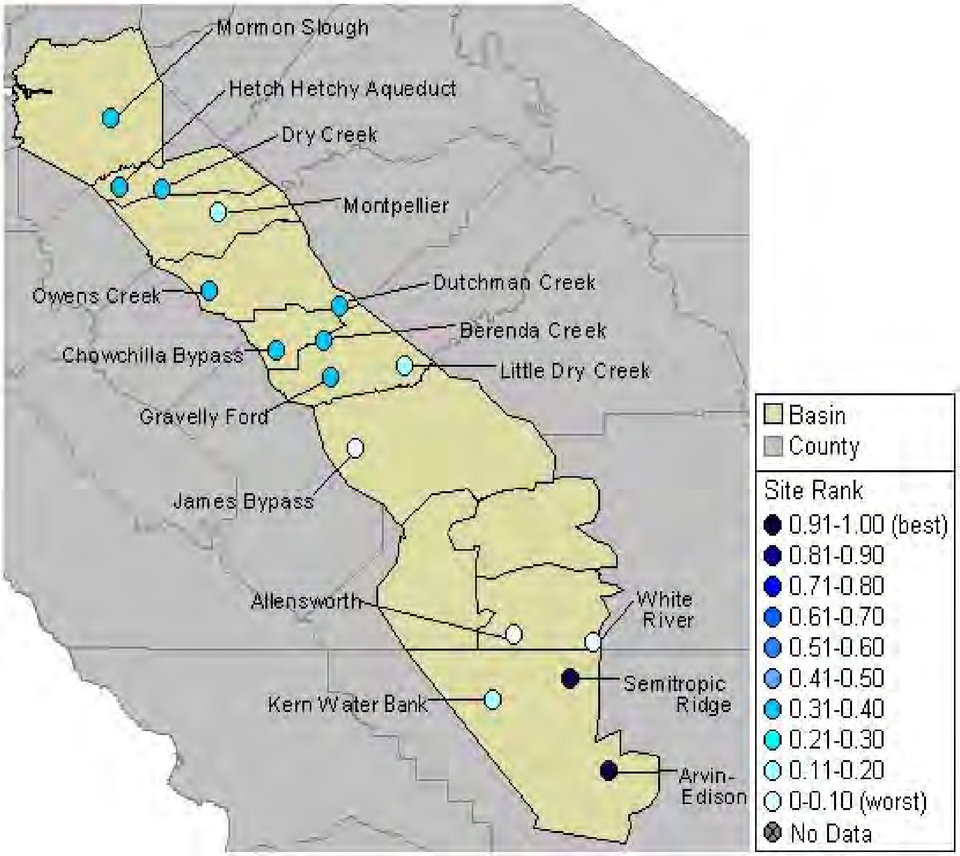


Figure 5.1.2: Spatial Distribution of Geology Sub-Index Values Across Potential Groundwater Banking Sites in the San Joaquin Valley



5.1.2 Comments on the San Joaquin Geology Sub-Index

The eastern Kern Basin sites (Arvin-Edison and Semitropic Ridge) emerge as well-suited for a groundwater banking project owing to the favorable geologic properties of the underlying northwestern Kern fan formation laid down by the Kern River. By comparison, sites on Tule and Kings River alluvial fans rank low. A large part of this discrepancy is due to a relative lack of information in the published literature on the specific alluvial fans associated with the sites. This lack of information forced us to set parameter scores based on fairly coarse descriptions found in regional mapping studies. Given the quality of the data, we erred on the side of caution in assigning the parameter scores. If these sites prove to be extremely suitable based on other components of the index, further research and testing of these alluvial deposits might be warranted.

In general, however, sites in the San Joaquin Valley demonstrate much less geologic variability than those identified in the Sacramento Valley. The influence of the geology sub-index on the overall index, then, should be viewed in comparative rather than absolute terms.

5.2 San Joaquin Valley Water Quality Sub-Index

As in the Sacramento Valley, the water quality sub-index in the San Joaquin Valley comprises four parameters: groundwater concentrations of arsenic, boron, lead and total dissolved solids. The methodology employed to assign scores to each of these parameters and to calculate the sub-index value is found in Section 3.2.

Water Quality Sub-Index Equation Key

Eq. 3.3: Water Quality Score = (As Score) + (B Score) + (Pb Score) + (TDS Score)
Eq. 3.4: Water Quality Sub-Index = 1.5*(Basin Score) + (Site Score)

5.2.1 Results of the San Joaquin Valley Water Quality Sub-Index

Groundwater quality parameter scores for both basins and sites in the San Joaquin Valley are given in Tables 5.2.1 and 5.2.2 respectively. Figure 5.2.1 illustrates these results spatially.

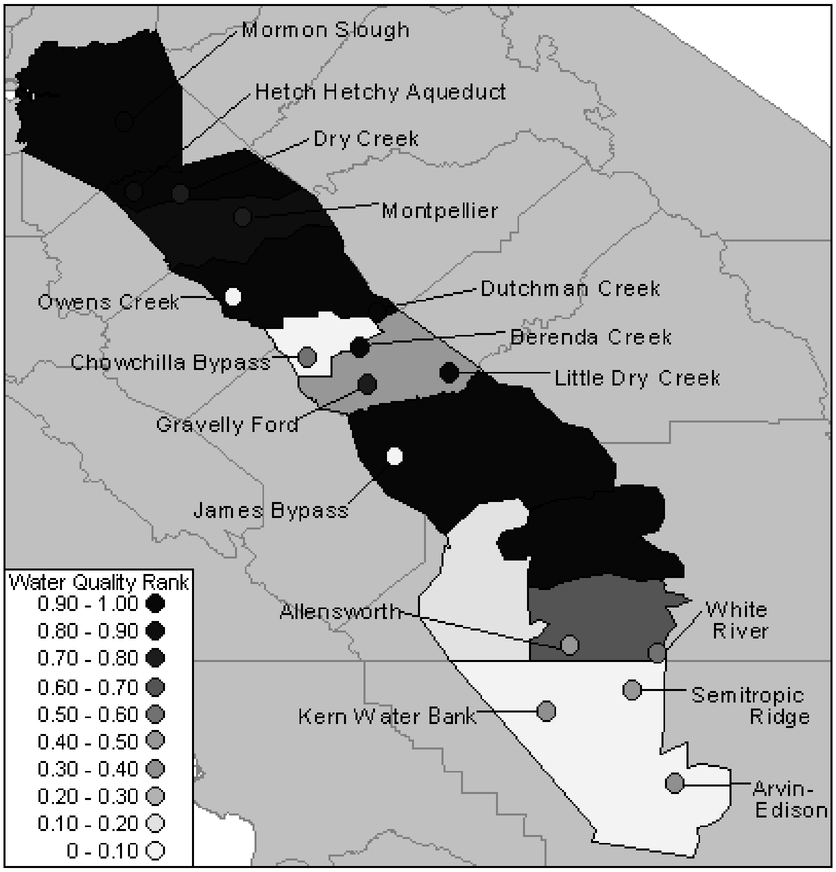
Table 5.2.1: San Joaquin Valley Basin Scores

Weighting Coefficient	1	1	1	1		
Basin Name	**As**	**B**	**Pb**	**TDS**	**Rank**	**%**
Modesto	9	9	7	9	34	1.00
Turlock	9	9	7	8	33	0.89
Merced	8	9	8	9	34	1.00
Chowchilla	6	10	3	6	25	0.00
Madera	7	10	5	7	29	0.44
Kings	9	10	7	8	34	1.00
Tule	5	10	7	9	31	0.67
Kaweah	9	10	7	8	34	1.00
Tulare Lake	5	4	8	9	26	0.11
Kern	3	10	5	7	25	0.00
San Joaquin	7	10	9	8	34	1.00

Table 5.2.2: San Joaquin Valley Site Scores

Weighting Coefficient	1	1	1	1		
Site Name	**As**	**B**	**Pb**	**TDS**	**Rank**	**%**
Dutchman Creek	9	10	8	9	36	1.00
Little Dry Creek	10	10	7	9	36	1.00
Mormon Slough	8	10	8	9	35	0.93
Berenda Creek	9	10	8	8	35	0.93
Hetch Hetchy Aqueduct	9	9	9	7	34	0.87
Dry Creek	9	9	9	6	33	0.80
Gravelly Ford	9	10	8	6	33	0.80
Montpellier	9	10	7	6	32	0.73
Chowchilla Bypass	6	10	7	6	29	0.53
White River	5	9	7	8	29	0.53
Allensworth	3	10	7	8	28	0.47
Semitropic Ridge	4	10	7	7	28	0.47
Kern Water Bank	3	10	8	6	27	0.40
Arvin-Edison	4	10	7	6	27	0.40
Owens Creek	5	5	9	3	22	0.07
James Bypass	8	2	7	4	21	0.00

Figure 5.2.1: Spatial Distribution of Basin and Site Water Quality Scores



These scores were used to calculate the water quality sub-index based on Equation 3.4. The results for potential banking sites in the San Joaquin Valley are found in Table 5.2.3.

In preparation for inclusion in the overall Hydrogeologic Suitability Index for the San Joaquin Valley, water quality sub-index values have been normalized between 1 (corresponding with best groundwater quality at the Dutchman Creek site) and 0 (corresponding with the poorest observed groundwater quality at the Kern Water Bank and Arvin-Edison sites) in the % column. These results are shown with reference to the overall rank and the spatial distribution in Figures 5.2.2 and 5.2.3.

Table 5.2.3: Water Quality Sub-Index Values for Potential Banking Sites in the San Joaquin Valley

Weighting Coefficient		1.5	1		
Site Name	**Basin**	**Basin Wide**	**Site Specific**	**Rank**	**%**
Dutchman Creek	Merced	1.00	1.00	2.50	1.00
Mormon Slough	San Joaquin	1.00	0.93	2.43	0.96
Hetch Hetchy Aqueduct	Modesto	0.87	1.00	2.30	0.89
Dry Creek	Modesto	0.80	1.00	2.20	0.84
Montpellier	Turlock	0.73	0.89	1.99	0.73
Little Dry Creek	Madera	1.00	0.44	1.94	0.71
Gravelly Ford	Madera	0.80	0.44	1.64	0.55
White River	Tule	0.53	0.67	1.47	0.46
Berenda Creek	Chowchilla	0.93	0.00	1.40	0.42
Allensworth	Tule	0.47	0.67	1.37	0.40
Owens Creek	Merced	0.07	1.00	1.10	0.26
James Bypass	Kings	0.00	1.00	1.00	0.21
Chowchilla Bypass	Chowchilla	0.53	0.00	0.80	0.11
Semitropic Ridge	Kern	0.47	0.00	0.70	0.05
Kern Water Bank	Kern	0.40	0.00	0.60	0.00
Arvin-Edison	Kern	0.40	0.00	0.60	0.00

Figure 5.2.2: Water Quality Sub-Index Ranking

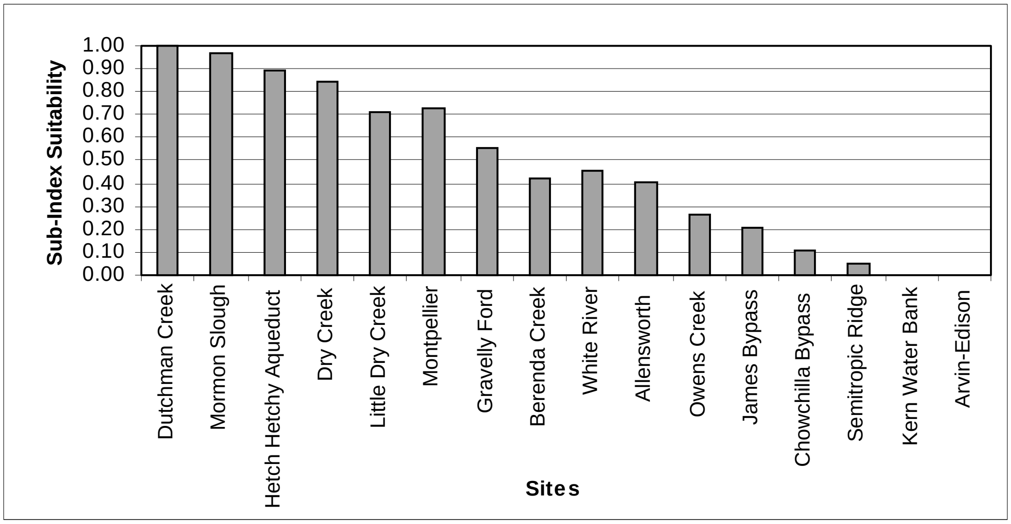
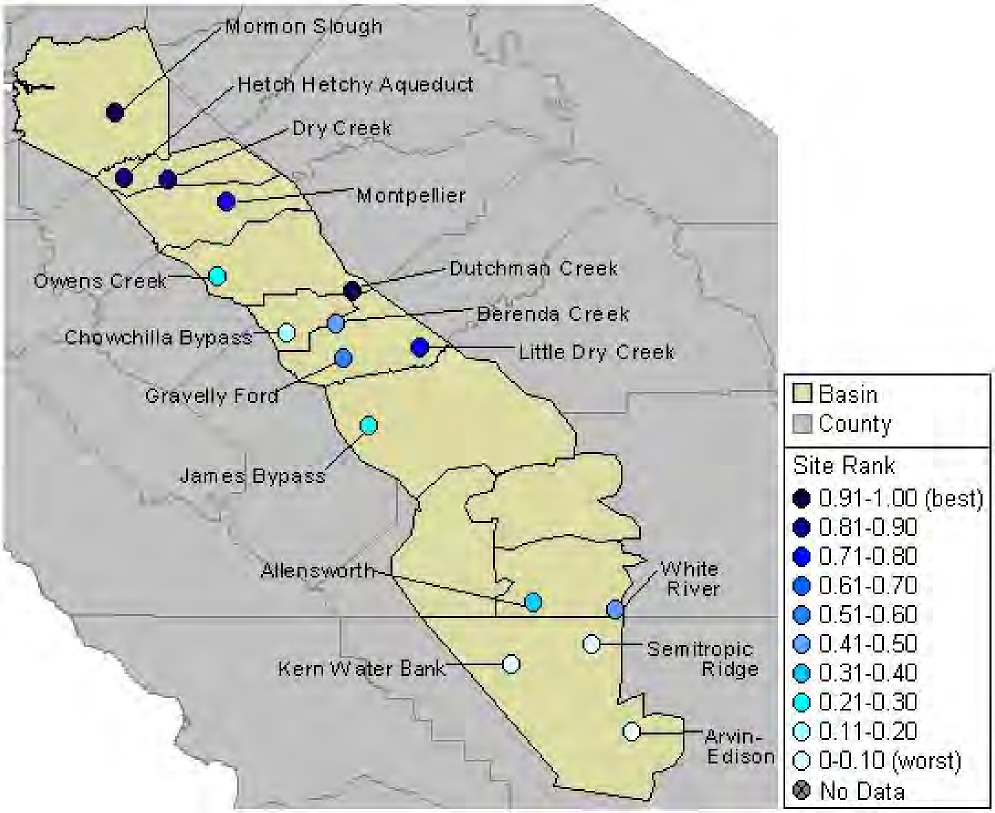


Figure 5.2.3: Spatial Distribution of Water Quality Sub-Index Values



5.2.2 Comments on the Water Quality Sub-Index

Excluding the western San Joaquin Valley, where groundwater quality is generally poor across wide areas and where no potential banking sites have been identified, groundwater in the San Joaquin Valley is characterized by the presence of spots of poor quality. Arsenic levels are particularly high in the southern part of the valley in Kern and Tulare Lake Basins. Boron levels peak in parts of Merced, Kings and Tulare Lake basins, a pattern that is mimicked by the distribution of elevated TDS measurements. Lead concentrations are fairly low throughout the valley.

This spatial pattern of groundwater quality points out the utility of the spreadsheet developed as part of this effort. In general, boron is of greatest concern to agricultural water users while arsenic is particularly problematic for municipal water providers. In calculating the water quality sub-index, equal weighting was given to each of these parameters. Someone interested in evaluating the implications of groundwater banking on either of these user communities may wish to weight the sub-index in favor of one of these parameters over the others.

5.3 San Joaquin Valley Soils Sub-Index

Parameters used to calculate the soils sub-index are described in Section 3.0.

Soils Sub-Index Equation Key

Eq. 3.5: Soils Sub-Index = (Thickness) [3(Permeability) + (pH)– 2(1 – Hardpan)]

5.3.1 Results for the San Joaquin Valley Soils Sub-Index

Parameter scores and the soils sub-index values for selected sites in the San Joaquin Valley are shown below in Table 5.3.1.

Table 5.3.1: Soils Sub-Index

Weighting Coefficient	1	3	2	1		
Site	**Thickness**	**Permeability**	**Hardpan**	**pH**	**Rank**	**%**
Hetch Hetchy Aqueduct	0.80	0.60	1.00	0.83	2.10	1.00
Dry Creek	0.75	0.31	0.96	0.79	1.25	0.71
Montpellier	0.48	0.75	0.85	0.74	1.28	0.72
Semitropic Ridge	0.78	0.20	1.00	0.70	1.01	0.63
Gravelly Ford	0.77	0.24	0.87	0.54	0.77	0.55
Little Dry Creek	0.66	0.40	0.55	0.80	0.73	0.54
Arvin-Edison	0.86	0.03	1.00	0.74	0.71	0.53
Kern Water Bank	0.76	0.01	1.00	0.69	0.55	0.48
Owens Creek	0.75	0.02	1.00	0.41	0.36	0.42
White River	0.52	0.06	0.85	0.80	0.35	0.41
Chowchilla Bypass	0.67	0.13	0.51	0.50	-0.05	0.28
Berenda Creek	0.75	0.23	0.11	0.85	-0.17	0.24
James Bypass	0.77	0.20	0.19	0.51	-0.40	0.16
Dutchman Creek	0.64	0.14	0.23	0.68	-0.27	0.20
Mormon Slough	0.75	0.02	0.00	0.76	-0.88	0.00

The resulting values are normalized between 1 (corresponding with the most favorable soils at the Hetch Hetchy Aqueduct site) and 0 (corresponding with the Mormon Slough site) in the % column. These are presented graphically in Figures 5.3.1 and 5.3.2, which show the relative rank and spatial distribution of the results.

Figure 5.3.1: Soils Sub-Index Rank

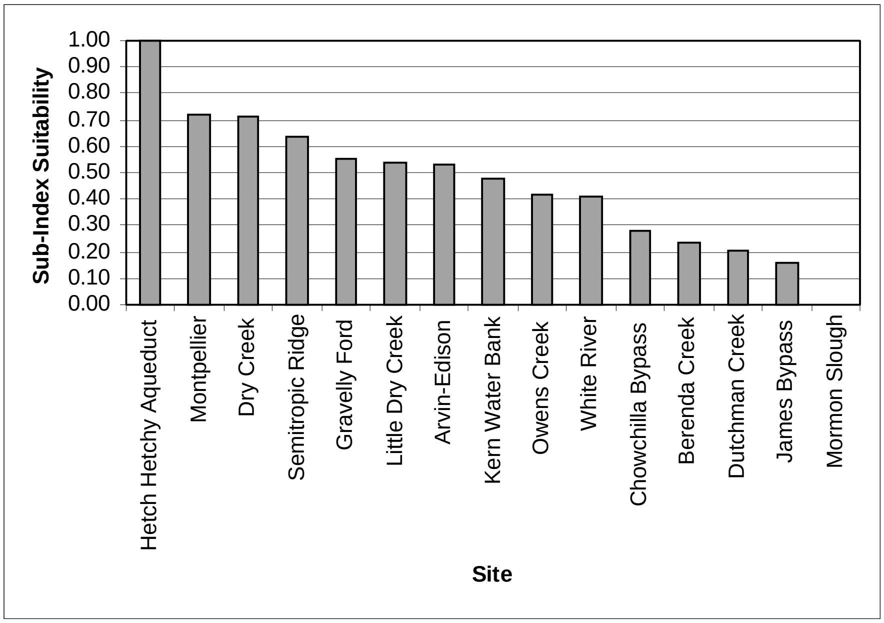
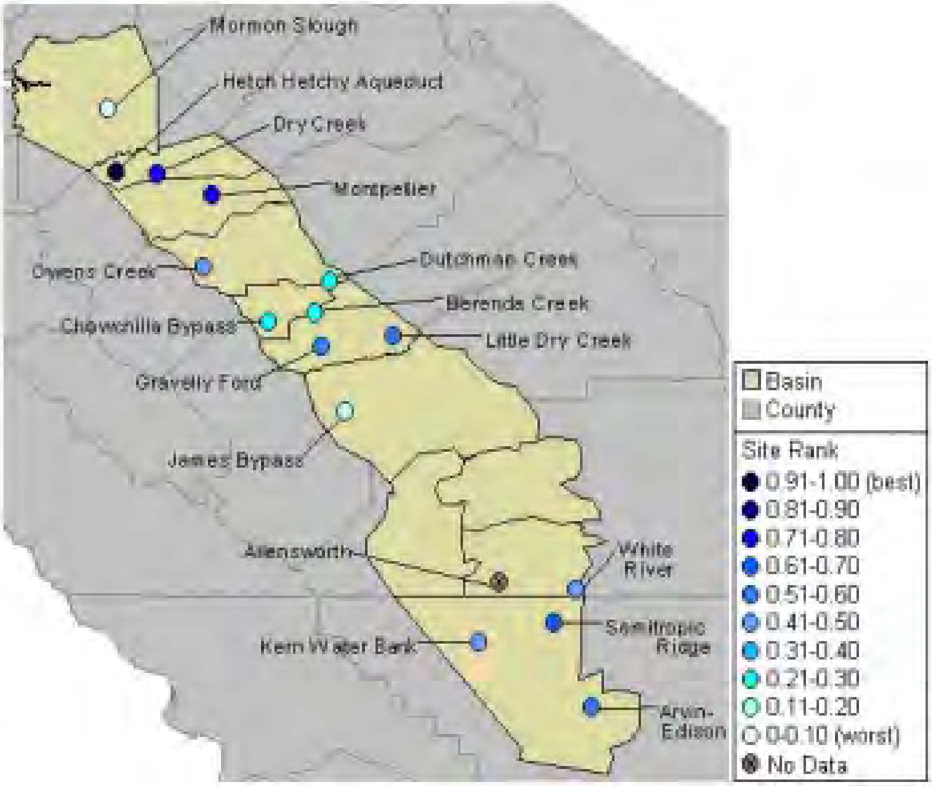


Figure 5.3.2: Spatial Distribution of Soils Sub-Index Values



5.3.2 Comments on the Soils Sub-Index

Based on the selected parameters, the Turlock and Merced basins appear to possess the most suitable soils in the San Joaquin Valley. Soils in this region are derived from material of Sierran origin deposited by the high-energy Tuolumne and Merced Rivers. The result is a generally more coarse assemblage of soils as compared with material deposited by lower-energy streams to the north and south.

While more complete soil data was available for the San Joaquin Valley than in the Sacramento Valley, one site, Allensworth, lacked published soils information. Owing to a lack of data, in calculating the overall Hydrogeologic Suitability Index this site will be assigned a zero in terms of the soils sub-index.

5.4 San Joaquin Valley Hydrologic Connection Sub-Index

In the San Joaquin Valley, an additional sub-index has been added to the core Hydrogeology Suitability Index dealing with the hydrologic connection between potential storage space located within existing cones of depression and the surrounding hydrologic system. Groundwater basins are not surface reservoirs. While exposed to losses due to evaporation and seepage, water stored behind a dam is largely under the direct control of reservoir operators. When water is required, it need only be released from the storage pool. Storage in a groundwater bank does not benefit from the same level of control. Aquifers are open systems within which the existing level of use and conditions in surrounding groundwater basins and overlying surface water bodies influence flow patterns. In such a system, there is no guarantee that water recharged to a groundwater bank will remain within the pore space of the aquifer material immediately below the banking site. In assessing the hydrogeologic suitability of potential sites in the San Joaquin Valley, it is important to understand the way in which banked water would interact with the surrounding hydrologic system.

The most rigorous way to understand these potential interactions is through the use of groundwater models that describe flow patterns within an aquifer under various conditions. While the development of project-specific groundwater models will certainly occur once promising groundwater banking sites are identified and project design begins, it was beyond the scope of the current effort to develop such a tool for all of the potential sites in the San Joaquin Valley. In order to assess the potential for interaction between banked water and the surrounding aquifer, a simple method based on measured water level data was developed.

This methodology begins with the supposition that water banked in the San Joaquin Valley will ideally be stored within large, well-defined, stable drawdown features within an aquifer. This statement is based on two assumptions. First, it is assumed that where such features occur, the existing patterns of groundwater use and aquifer recharge leave a significant portion of the aquifer material perpetually unsaturated and available for long-term storage. Second, it is assumed that once recharge water joins the water table within such a large, well-defined, stable feature, it would be contained within the cone of depression and would not flow away from the recharge site. The methodology used to assess the degree of hydrologic connection between banked water and the surrounding aquifer relies upon analysis of the size and stability of target drawdown features.

5.4.1 San Joaquin Valley Hydrologic Connection Sub-Index Parameters

The components used in the hydrologic connection sub-index were all derived from data included in the semi-annual well survey conducted by the California Department of Water Resources. An example of the type of data contained in the survey is shown in Table 5.4.1.

Table 5.4.1: Water Contour Data for Turlock Basin, 6/1/77 to 12/31/77

UTM East	UTM North	WSE	GSWS	SWN	Meas. Date	UTM Zone
707008	4167178	118.0	82.0	03S12E33L01M	11/04/1977	10
672518	4159172	49.7	12.3	04S08E25D01M	11/01/1977	10
672572	4157724	48.6	9.4	04S08E25N01M	11/01/1977	10
670810	4158643	34.0	16.0	04S08E27H01M	11/01/1977	10
670808	4157564	44.4	8.6	04S08E34A01M	11/01/1977	10
669361	4157504	39.4	10.6	04S08E34D01M	11/01/1977	10
679642	4165707	33.4	24.6	04S09E03B01M	10/18/1977	10
677098	4165374	29.0	39.0	04S09E05H01M	10/14/1977	10

In the table, "UTM East", "UTM North" and "UTM Zone" are used to specify the physical location of wells included in the survey. The column heading SWN denotes the state well number, which makes reference to the California Public Lands Survey. The date of the semi-annual measurement at a well is provided under the heading "Meas. Date". We excluded from our analysis any data for which problems were encountered during measurement (as recorded during data collection). Hydrologic data related to the water surface elevation and the difference between the ground surface elevation and the water surface elevation are found under the "WSE" and "GSWS" headings, respectively (the sum of WSE and GSWS should yield the land surface elevation at the measurement site).

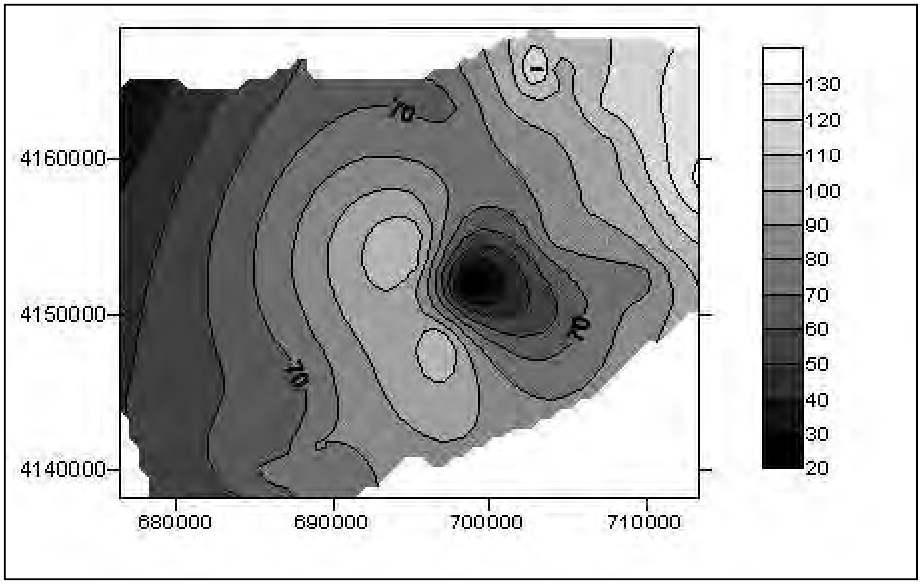
Data highlighted in Table 5.4.1 were used to define the parameters for the hydrologic connection sub-index. Water surface elevation data for the entire San Joaquin Valley were collected from Fall 1977 (selected to represent dry year conditions) and Fall 1997 (a wet water year) surveys. These data were used to develop approximate water table contour maps for each of the basins in the San Joaquin Valley. Figure 5.4.1 is an example of a map developed for the Turlock Basin based on the Fall 1977 survey. The large closed depression in the figure is located beneath the Montpellier site identified in Figure 2.0.2.

These maps should be considered approximate in that the wells included in the semi-annual survey were not specifically designed to track the position of the water table. Most are private wells that are screened across several hundred feet of aquifer material. As such, the water level observed in the well is an integrated sample of heads encountered both at the water table and at depth below the water table. In cases where significant flow-restricting horizons exist in the interval spanned by the well screen, these deeper heads may be quite different than the actual elevation of the water table surface. While an attempt was made to screen out problematic wells, some of the heads used to develop the contour maps most certainly did not reflect the true water table elevation at a given location.

Nonetheless, the contour maps developed as part of this analysis, found in Appendix E, capture the general location and scale of major cones of depression known to exist in the San Joaquin Valley. Lacking the resource to develop more accurate local water table maps, we used our

Figure 5.4.1: Turlock Basin Fall 1977 WSE Contours

(Elevation in feet above MSL)



basin scale maps to estimate the storage volume located within a cone of depression using a standard specific yield estimate of 0.2. In the case of the depression below the Montpellier site, a horizontal plane set at 75 ft. capped approximately 208 TAF of available storage during Fall 1977. Based on the estimated basin scale water table contour maps developed during the fall surveys of 1977 and 1997, two parameters were defined for use in the hydrologic connection sub-index.

Maximum Overall Size of Water Table Depressions

The larger of the estimated available storage volumes calculated based on data from the Fall 1977 and Fall 1997 surveys was selected to represent the maximum overall size of water table depressions parameter. We anticipated the available storage volume would be larger during 1977 owing to the extremely dry conditions encountered at that time. We discovered, however, that some locations manifested larger available storage volumes during the wet 1997 water year. This is presumably due to the fact that groundwater overdraft during the 20 intervening years masked any water table recovery associated with higher levels of aquifer recharge.

Inter-Annual Water Table Change

Nonetheless, changing levels of aquifer recharge do contribute to fluctuations in the water table surface that can be observed between dry and wet periods. Groundwater basins that experience significant changes in water levels, and hence available storage volumes, generally benefit from a high degree of natural recharge during wet periods. If the storage of banked water would limit the ability to capture a portion of this natural recharge, then the project could create conflicts with historic groundwater users. Any such fluctuations can be described in the following equation used to define the inter-annual water table change parameter of the hydrologic connection sub-index.

$$\text{Inter-Annual Change} = (V_{77F} - V_{97F}) / \text{Max. Volume} \tag{5.2}$$

where V_{77F} = volume of a basin in Fall 1977
and V_{97F} = volume of a basin in Fall 1997

Because the effects of long-term overdraft can mask water table recovery associated with enhanced recharge during wet years, Equation 5.2 occasionally produces negative numbers. A site in overdraft provides a unique opportunity for a groundwater banking project because, not only would the site have a large depression available for storage, but the storage of water there could be used to provide benefits to overlying groundwater pumpers if some portion of the banked water could be used to slow down or reverse incipient water table declines.

5.4.2 San Joaquin Valley Hydrologic Connection Sub-Index Weighting Factors

As in the case of the sub-indices included in the core index, calculation of the hydrologic connection sub-index can be influenced by the assignment of appropriate weighting factors. As the size of the cone of depression is the most important feature in determining what scale of a project could be pursued at a potential groundwater banking site, this parameter was weighted by a factor of two. In addition, the inter-annual change parameter should be subtracted from one so that a basin that experiences a small rise in the water table between wet and dry years (suggesting a small amount of hydrologic connection with the surrounding hydrology) would score higher than a basin where large fluctuations occur, presumably in response to significant interaction between the aquifer and the surrounding hydrologic features. In addition, for sites in overdraft (the inter-annual change parameter is negative), where banking could contribute to water table recovery, this subtraction would enhance the suitability of the site. Each of these assumptions is contained in the following equation used to calculate the hydrologic connection sub-index.

$$\text{Hydrologic Connection Sub-Index} = 2*\text{Max. Volume} + (1 - \text{Inter-Annual Change}) \tag{5.3}$$

5.4.3 Results for the San Joaquin Valley Hydrologic Connection Sub-Index

Applying Equation 5.3 to the estimated water table elevation data derived from the available data produces the hydrologic connection sub-index values shown in Table 5.4.2. These values have been normalized between 1 (corresponding with the Kern Water Bank site) and 0 (corresponding with the Dry Creek site) in the % column. Normalized results are shown in terms of relative rank in Figure 5.4.2 and spatial distribution in Figure 5.4.3.

Table 5.4.2: Hydrologic Connectivity Sub-Index Table

Site	Max. Vol.	Annual	Rank	%
Kern Water Bank	21.61	-0.40	44.62	1.00
Allensworth	7.77	-0.83	17.37	0.39
James Bypass	6.13	0.18	13.08	0.29
Semitropic Ridge	6.07	0.79	12.35	0.27
Mormon Slough	5.19	0.67	10.71	0.24
Little Dry Creek	4.37	-0.94	10.68	0.24
Gravelly Ford	3.61	0.06	8.15	0.18
Dutchman Creek	1.54	-0.41	4.49	0.10
Arvin-Edison	1.55	-0.35	4.45	0.10
White River	1.29	0.46	3.12	0.07
Montpellier	1.04	0.22	2.86	0.06
Chowchilla Bypass	0.32	-0.91	2.55	0.05
Owens Creek	0.79	0.25	2.33	0.05
Berenda Creek	0.06	-0.96	2.08	0.04
Hetch Hetchy	0.01	-0.67	1.69	0.03
Dry Creek	0.02	0.87	0.17	0.00

Figure 5.4.2: Hydrologic Connection Sub-Index Rank

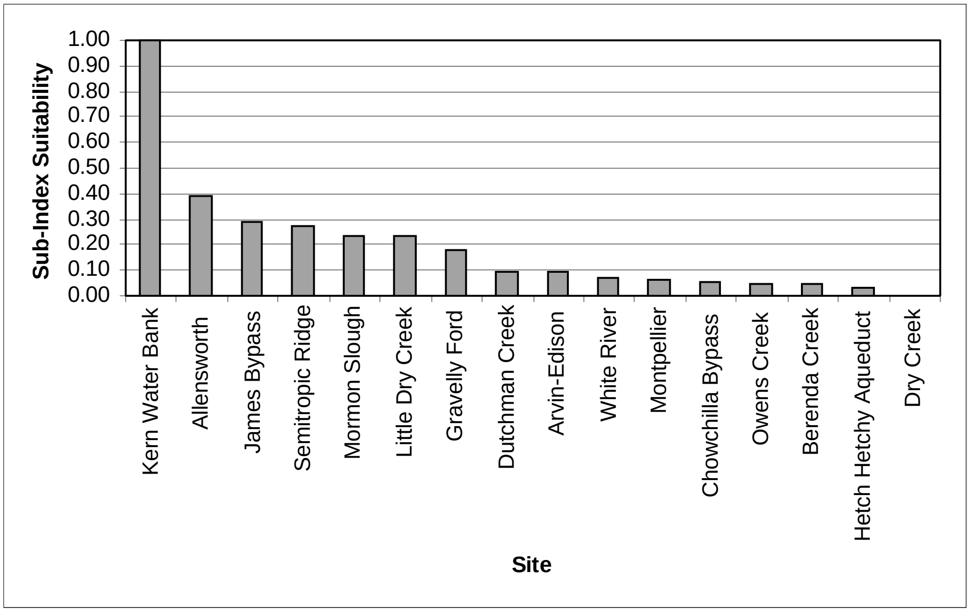
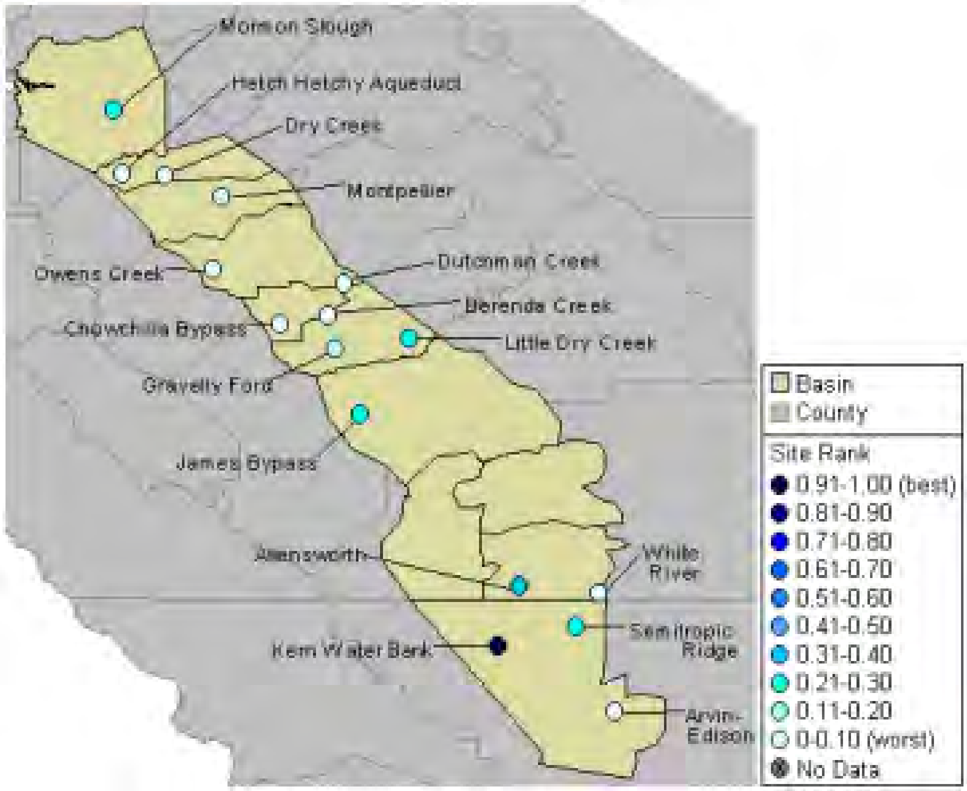


Figure 5.4.3: Spatial Distribution of Hydrologic Connection Sub-Index Values



5.4.4 Comments on the Hydrogeologic Connectivity Index

The Kern Water Bank dwarfs the rest of the potential groundwater banking sites in the San Joaquin Valley with respect to the hydrologic connection sub-index. This site overlies what was a large depression in 1977 and has been the locus of an active groundwater banking project for the past decade. While it no longer merits the label of a potential site, it was included in the analysis for comparative value.

Another cluster of relatively promising sites lies in the vicinity of the San Joaquin River. The Little Dry Creek, Gravelly Ford and James Bypass sites all score relatively high. The opportunity to manage these sites in conjunction with reoperation of Friant Dam on the San Joaquin likely merits additional evaluation.

5.5 San Joaquin Valley Hydrogeologic Suitability Index

Having developed the four relevant sub-indices, the overall Hydrogeologic Suitability Index for potential groundwater banking sites in the San Joaquin Valley was calculated based on the following equation.

$$\boxed{\text{Hydrogeologic Suitability Index} = (\text{Geology}) + 2*(\text{Water Quality}) + (\text{Soils}) + 0.5*(\text{Hydrologic Connection})} \tag{5.4}$$

The results of this analysis are shown in Table 5.5.1 with the normalized values between 1 (corresponding with the Hetch Hetchy Aqueduct) and 0 (corresponding with James Bypass) shown in the % column. These results are shown graphically in Figures 5.5.1 and 5.5.2, which present the relative rank and spatial distribution, respectively.

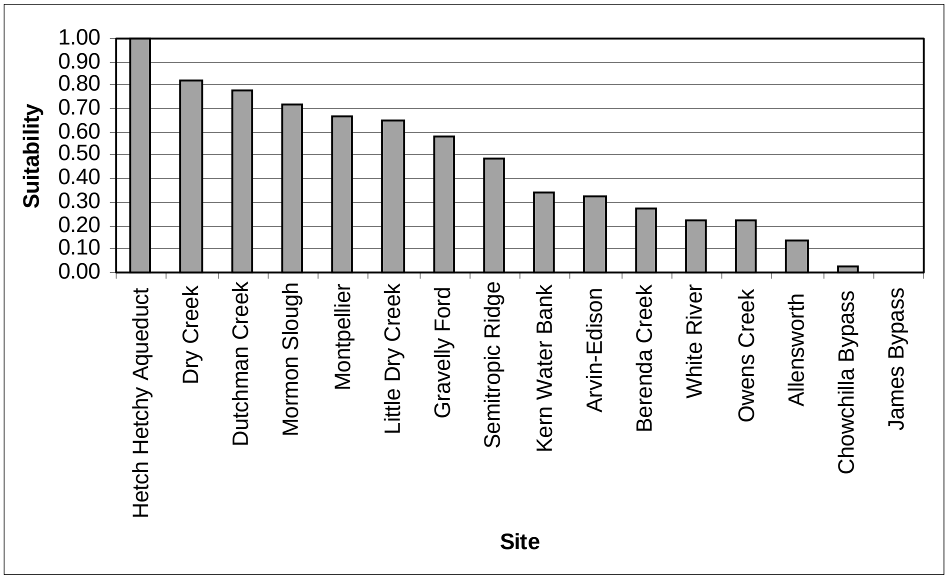
Table 5.5.1: San Joaquin Valley Hydrogeologic Suitability Index

Weighting Coefficient	1	2	1	0.5		
Site	**Geology**	**Water Quality**	**Soils**	**Hydrologic Connectivity**	**Rank**	**%**
Hetch Hetchy Aqueduct	0.40	0.89	1.00	0.03	3.22	1.00
Dry Creek	0.40	0.84	0.71	0.00	2.80	0.82
Dutchman Creek	0.40	1.00	0.20	0.10	2.70	0.78
Mormon Slough	0.40	0.96	0.00	0.24	2.57	0.72
Montpellier	0.20	0.73	0.72	0.06	2.45	0.67
Little Dry Creek	0.20	0.71	0.54	0.24	2.39	0.65
Gravelly Ford	0.40	0.55	0.55	0.18	2.23	0.58
Semitropic Ridge	1.00	0.05	0.63	0.27	2.01	0.48
Kern Water Bank	0.20	0.00	0.48	1.00	1.68	0.34
Arvin-Edison	1.00	0.00	0.53	0.10	1.63	0.32
Berenda Creek	0.40	0.42	0.24	0.04	1.52	0.28
White River	0.00	0.46	0.41	0.07	1.39	0.22
Owens Creek	0.40	0.26	0.42	0.05	1.39	0.22
Allensworth	0.00	0.40	0.00*	0.39	1.19	0.14
Chowchilla Bypass	0.40	0.11	0.28	0.05	0.94	0.03
James Bypass	0.00	0.21	0.16	0.29	0.87	0.00

* In cases where values were missing, the value zero was used.

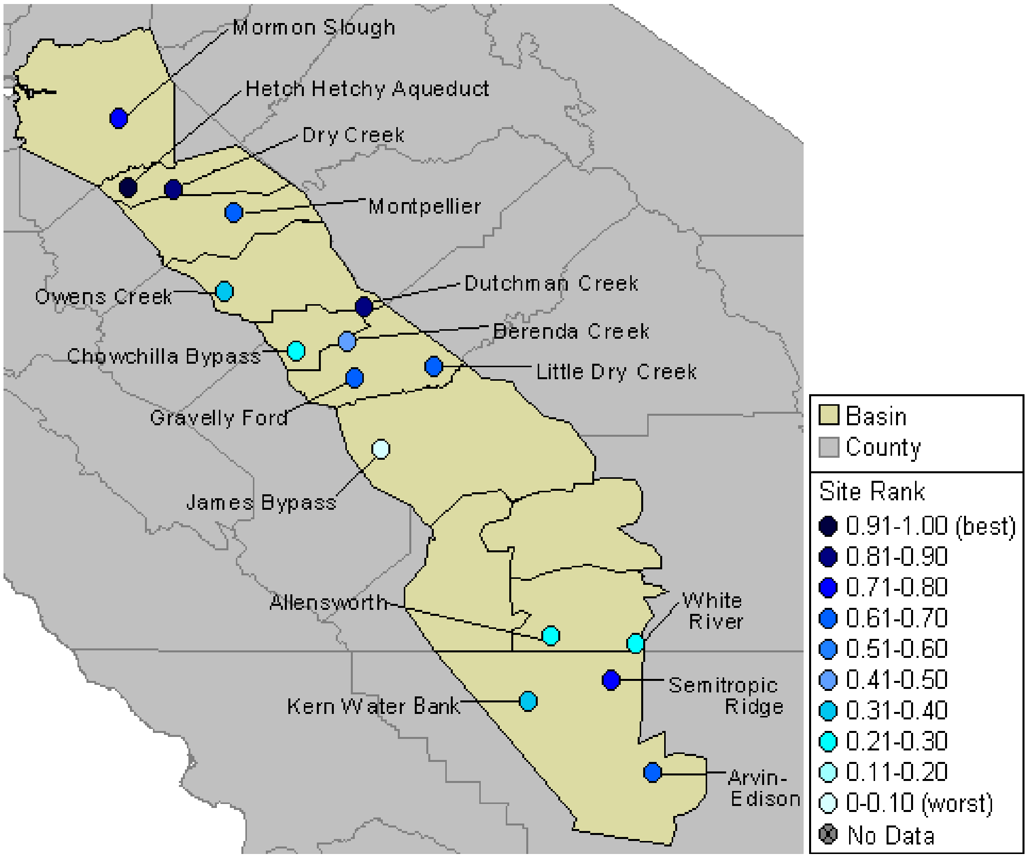
In this analysis, the water quality sub-index was weighted by 2 to stress its importance to the ultimate users of banked groundwater. In the San Joaquin Valley, the geology sub-index only receives a weighting factor of 1 (as opposed to 2 in the Sacramento Valley) in order to reflect the fact that the data do not suggest as clear a differentiation between sites in terms of this important characteristic. Soils receive a weight of 1 to reflect the fact that while they can exert important controls on the operation of recharge basins, problematic soils can be removed as part of project construction, although this would increase the overall cost of the project. The hydrologic connection sub-index receives a weight of 1 because, while the information on the water table depression size and stability is extremely important, the approach taken here is based on the hydrologic response of the system under existing management conditions. The initiation of storage and recovery operations at a potential site would substantially alter these conditions. As previously mentioned, the best way to evaluate this possibility is through the application of groundwater models—an exercise that was beyond the scope of the current investigation. In the event that modeling results become available, it would be possible to increase the weighting on this sub-index.

Figure 5.5.1: San Joaquin Valley Hydrogeologic Suitability Index Rank



It should be pointed out that the ranking depicted in Figure 5.5.1 is purely a function of the numerical values assigned to each of the components and the weighting coefficients shown in Equation 5.4. It is possible that others interested in groundwater banking in the San Joaquin Valley would apply different component values and weighting coefficients. In order to allow for further exploration of geology, groundwater quality, soils and the degree of hydrologic connection on the suitability of potential groundwater banking sites in the San Joaquin Valley, the information used to generate the ranking in Table 5.5.1 has been made available in the spreadsheet developed as part of this effort. In this spreadsheet, any of the values or weighting coefficients applied to the sub-indices may be changed and the new results can be viewed in tables and graphs similar to those in Table 5.5.1 and Figure 5.5.1.

Figure 5.5.2: Spatial Distribution of Hydrogeologic Suitability Index Values



6.0 Conclusions

A recent review of an attempt to develop an Environmental Sustainability Index (ESI) that could be applied to nations across the world (found in the 01/25/01 edition of *The Economist*) seized upon two major problems inherent to the development of comparative indices. First, "a tricky challenge…is to decide how to weigh each indicator". Second, "another challenge remains the paucity of good data. By forging ahead anyway, the report risks lending a quantitative gravitas to conclusions that are based on still-sketchy data".

The first critique stems from the fact that the ESI gives equal weight to all its 22 indicators. The authors of the ESI accepted this criticism, but explained that their database will soon be available on CD-ROM. Critics will then be able to use whatever weightings they prefer. The authors of the ESI responded to the second critique by arguing that they have created a framework that exposes the data deficiencies, and so spurs others to remedy them. Future versions of the report, they point out, can only get better. In fact, the authors conclude "the chief virtue of this index is that it begins the process of shifting environmental debates on to firmer foundations, underpinned by data and a greater degree of analytic rigor".

While our development of a Hydrogeologic Suitability Index for potential groundwater banking sites in the Central Valley is a much less weighty endeavor than the development of the ESI, we anticipate that similar criticisms will be directed at this effort. Rather than weight each of our sub-indices equally, however, we made an attempt to highlight what we perceive to be the relative importance of the geologic setting and water quality sub-indices. By making the aforementioned Excel workbook available on the web, we encourage all those interested in groundwater banking in California to use whatever weightings they prefer. While the data used in this effort are likely better than those available to the authors of the ESI, we have pointed out that several compromises were made in order to assemble the minimum suite of data used to develop the Hydrogeologic Suitability Index. We encourage those with access to better information to improve upon our effort by bringing this information to bear on the on-line database. This process of refinement will only improve the quality of our effort.

As a starting point, however, we feel that the Hydrogeologic Suitability Index reveals several interesting findings in terms of potential projects that should be considered for more refined analysis. Notably, we found that the groundwater basins in the Sacramento Valley are generally more favorable in terms of their hydrogeologic suitability for groundwater banking. As has been mentioned on several occasions in this report, this finding raises a number of complicated legal and institutional issues related to the fact that these basins are not currently endowed with substantial volumes of unsaturated aquifer material ready to be used for storage. While these issues will by no means be simple to resolve, the quality of these basins from a purely hydrogeologic perspective suggests strongly that the effort should be made to resolve them.

In the Sacramento Valley, the best opportunities for groundwater banking seem to cluster near the northern end of the valley, with Stone Valley and Stoney Creek Fan leading the pack. The geology in particular under these sites is well-suited for a banking project.

In the San Joaquin Valley, there is no clear geographic gradient of favorable to poor sites. Clusters of favorable sites exist in Modesto, Madera and Kern basins. Both soils and hydrologic connection vary greatly in the San Joaquin Valley, which could account for the discontinuous distribution.

In concluding their review of the Environmental Sustainability Index, the commentators concluded that it "is a thoughtful step in the right direction". While much work remains to be done in translating the promise of groundwater banking to actual yield-enhancing projects, we hope that the Hydrogeologic Suitability Index described in this report will ultimately be viewed in a similar light.

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Appendix A: Raw Water Quality Data

Sacramento Valley

Arsenic Dissolved (µg/L as As)

Longitude	Latitude	Result	Date
-122.2881	39.0125	1	9/19/86
-122.2806	39.0222	1	9/19/86
-122.2794	39.0233	10	9/19/86
-122.5389	40.2806	1	8/9/83
-122.5389	40.2806	1	8/5/83
-122.5389	40.2806	1	7/31/83
-122.5389	40.2806	1	7/12/83
-122.5389	40.2806	1	7/9/83
-121.6128	38.7083	9	9/30/82
-121.3694	38.6414	1	9/29/82
-121.3575	38.6006	2	9/29/82
-121.4028	38.6167	2	9/29/82
-121.42	38.3025	38	9/28/82
-121.4583	38.5233	5	9/28/82
-121.4647	38.5097	4	9/28/82
-121.305	38.6508	1	9/27/82
-121.3322	38.6183	1	9/27/82
-121.4517	38.3889	11	9/24/82
-121.2764	39.0158	1	9/24/82
-121.2764	39.0158	1	9/24/82
-121.4156	38.3803	6	9/24/82
-121.2914	38.5964	1	9/23/82
-121.4372	38.4178	17	9/23/82
-121.4453	38.4364	3	9/23/82
-121.4725	38.4197	11	9/23/82
-121.2861	38.5672	1	9/23/82
-121.2786	38.5439	1	9/23/82
-121.305	38.2628	11	9/22/82
-121.3822	38.6647	2	9/21/82
-121.3847	38.6581	1	9/21/82
-121.38	38.7119	4	9/21/82
-121.5269	38.2408	7	9/20/82
-121.5325	38.2828	16	9/20/82
-121.3086	38.705	1	9/17/82
-121.6025	38.1633	17	9/17/82
-121.2844	38.6842	1	9/17/82
-121.3317	38.6739	1	9/17/82
-121.3411	38.67	2	9/16/82
-121.3267	38.2411	7	9/15/82
-121.5478	38.6011	12	9/10/82
-121.3372	38.8728	2	9/9/82
-121.3372	38.8728	2	9/9/82
-121.2639	38.8858	1	9/9/82
-121.2639	38.8858	1	9/9/82
-121.3736	38.9822	2	9/7/82
-121.3736	38.9822	2	9/7/82
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-121.9878	38.6083	1	9/8/81
-121.9494	38.6675	1	9/8/81
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-122.0172	38.8061	9	9/2/81
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-121.9458	38.3514	1	7/10/74
-122.1867	39.2772	1	5/31/74

Boron Dissolved (µg/L as B)

Longitude	Latitude	Result	Date
-122.279	39.0233	4600	9/19/86
-122.288	39.0125	269	9/19/86
-122.281	39.0222	1000	9/19/86
-122.539	40.2806	80	8/9/83
-122.539	40.2806	100	8/5/83
-122.539	40.2806	110	7/31/83
-122.539	40.2806	50	7/12/83
-122.539	40.2806	130	7/9/83
-121.613	38.7083	1600	9/30/82
-121.369	38.6414	20	9/29/82
-121.358	38.6006	10	9/29/82
-121.403	38.6167	20	9/29/82
-121.420	38.3025	60	9/28/82
-121.458	38.5233	40	9/28/82
-121.465	38.5097	30	9/28/82
-121.305	38.6508	60	9/27/82
-121.332	38.6183	10	9/27/82
-121.276	39.0158	10	9/24/82
-121.416	38.3803	30	9/24/82
-121.452	38.3889	40	9/24/82
-121.276	39.0158	10	9/24/82
-121.445	38.4364	400	9/23/82
-121.437	38.4178	40	9/23/82
-121.279	38.5439	40	9/23/82
-121.286	38.5672	20	9/23/82
-121.291	38.5964	20	9/23/82
-121.473	38.4197	40	9/23/82
-121.305	38.2628	160	9/22/82

-121.380	38.7119	20	9/21/82
-121.385	38.6581	510	9/21/82
-121.382	38.6647	100	9/21/82
-121.527	38.2408	1400	9/20/82
-121.533	38.2828	60	9/20/82
-121.309	38.7050	80	9/17/82
-121.284	38.6842	40	9/17/82
-121.332	38.6739	220	9/17/82
-121.603	38.1633	120	9/17/82
-121.341	38.6700	20	9/16/82
-121.327	38.2411	140	9/15/82
-121.548	38.6011	230	9/10/82
-121.337	38.8728	170	9/9/82
-121.337	38.8728	170	9/9/82
-121.264	38.8858	4500	9/9/82
-121.264	38.8858	4500	9/9/82
-121.374	38.9822	530	9/7/82
-121.374	38.9822	530	9/7/82
-121.342	38.4133	140	9/7/82
-121.988	38.6083	180	9/8/81
-121.949	38.6675	1500	9/8/81
-122.068	38.7092	690	9/3/81
-122.053	38.7597	170	9/2/81
-122.017	38.8061	1100	9/2/81
-122.033	38.8161	210	9/2/81
-121.618	38.6458	3000	9/1/81
-121.563	38.6186	100	9/1/81
-121.523	38.3611	70	8/31/81
-121.558	38.3708	430	8/31/81
-121.998	38.5292	230	8/28/81
-121.972	38.5600	270	8/28/81
-121.556	38.5117	230	8/27/81
-121.515	38.5411	70	8/27/81
-121.546	38.5464	1500	8/27/81
-121.581	38.5342	1200	8/27/81
-121.651	38.5753	1300	8/26/81
-121.686	38.5022	590	8/26/81
-121.694	38.5206	860	8/26/81
-121.644	38.5089	1100	8/26/81
-121.756	38.5319	720	8/26/81
-121.693	38.5567	1000	8/25/81
-121.799	38.5461	530	8/24/81
-121.833	38.5506	470	8/20/81
-121.911	38.5906	1100	8/20/81
-121.936	38.7039	2500	8/19/81
-122.016	38.7442	290	8/19/81
-122.198	38.8108	500	8/17/81
-121.869	38.6642	1600	8/13/81
-121.886	38.7206	290	8/13/81
-121.727	38.5828	1100	8/12/81
-121.729	38.6181	1400	8/12/81
-121.785	38.6414	2300	8/12/81
-121.710	38.6000	1200	8/12/81
-121.765	38.6869	1800	8/11/81
-121.761	38.6631	1800	8/11/81
-121.729	38.6625	2000	8/11/81
-121.808	38.6781	1900	8/10/81
-122.059	38.7597	1400	8/10/81
-122.023	38.9150	150	7/30/81
-121.704	38.1597	980	9/23/80
-121.931	38.3247	470	9/16/80
-121.997	38.3411	540	9/12/80
-121.953	38.4039	60	9/12/80
-121.808	38.2467	1800	9/11/80
-121.824	38.2850	650	9/11/80
-121.966	38.4425	40	9/10/80
-121.918	38.4208	0	9/10/80
-121.893	38.3225	530	9/4/80
-121.889	38.4900	540	9/3/80
-121.933	38.3539	260	9/3/80
-121.712	38.3575	1600	9/3/80
-121.858	38.4206	230	9/3/80
-121.693	38.4011	740	9/2/80
-121.803	38.3367	410	9/2/80
-121.804	38.4214	530	8/28/80
-121.722	38.4869	690	8/27/80
-121.725	38.4594	540	8/27/80
-121.897	38.4508	90	8/26/80
-121.983	38.4975	580	8/26/80
-121.720	38.5028	570	8/25/80
-121.683	38.5822	1400	8/1/79
-121.674	38.5631	1300	8/1/79
-121.693	38.5644	1200	8/1/79
-121.674	38.5819	1300	8/1/79
-121.904	38.5728	670	7/31/79
-121.821	38.5836	730	7/31/79
-121.765	38.5839	930	7/31/79
-121.804	38.5475	390	7/31/79
-121.933	38.5967	420	7/31/79
-121.759	38.6122	1400	7/31/79
-121.802	38.6225	1400	7/31/79
-121.780	38.5961	910	7/31/79
-121.982	38.6908	2200	7/26/79
-121.845	38.5300	360	7/26/79
-121.961	38.6306	630	7/26/79
-121.852	38.5150	360	7/26/79
-121.823	38.6911	1600	7/26/79
-121.885	38.5472	410	7/26/79
-121.932	38.8372	200	7/25/79
-121.729	38.7200	2400	7/25/79
-121.722	38.6844	1600	7/25/79
-121.824	38.7647	2000	7/25/79
-121.745	38.7422	1600	7/25/79
-121.957	38.7175	1600	7/25/79
-121.947	38.7158	2200	7/25/79
-122.007	38.7233	1600	7/25/79
-121.858	39.6158	20	6/22/79
-121.802	38.7433	460	6/7/79
-121.820	38.7431	1700	6/7/79
-121.885	38.8161	440	6/7/79
-121.877	38.7714	130	6/7/79
-122.017	38.8061	470	6/7/79
-122.007	38.7233	1600	6/6/79
-121.998	38.7389	1200	6/6/79
-121.950	38.6419	610	6/6/79
-121.779	38.7431	4000	6/6/79
-121.961	38.6306	1900	6/6/79
-121.981	38.6703	500	6/6/79
-121.982	38.6908	2000	6/6/79
-121.988	38.7442	530	6/6/79
-121.957	38.7175	1800	6/6/79
-121.969	38.5808	710	6/6/79
-122.036	38.6928	350	6/6/79
-121.736	38.6625	1700	6/5/79
-121.729	38.7200	470	6/5/79
-121.835	38.5744	560	6/5/79
-121.773	38.6550	1700	6/5/79
-121.722	38.6844	1700	6/5/79
-121.723	38.6272	1500	6/5/79
-121.802	38.6225	1600	6/5/79
-121.756	38.6397	1800	6/5/79
-121.821	38.5836	700	6/5/79
-121.693	38.5644	1200	6/4/79
-121.734	38.6081	580	6/4/79
-121.703	38.5317	1000	6/4/79
-121.804	38.5475	340	6/4/79
-121.772	38.5736	1200	6/4/79
-121.726	38.6533	1000	6/4/79
-121.765	38.5839	1100	6/4/79
-121.767	38.5800	910	6/4/79
-122.126	39.4292	100	8/3/77
-121.762	39.6708	20	9/9/76
-121.764	39.7033	20	9/9/76
-121.795	39.6639	20	9/9/76
-121.801	39.7008	20	9/9/76
-121.799	39.7558	160	9/9/76
-121.669	39.5492	20	9/9/76
-121.645	39.5561	20	9/9/76
-121.686	39.5519	20	9/9/76
-121.778	39.6231	20	9/8/76
-121.699	39.6022	20	9/8/76
-121.744	39.5942	8	9/8/76
-121.613	39.5925	8	9/8/76
-121.711	39.5736	20	9/8/76
-121.764	39.5517	20	9/8/76
-121.711	39.5492	20	9/8/76
-121.668	39.6092	20	9/8/76
-121.699	39.4594	20	9/8/76
-121.487	39.4353	40	9/7/76
-122.011	38.9989	700	9/7/76
-121.544	39.4447	8	9/7/76
-121.583	39.4631	360	9/7/76
-121.689	39.4906	20	9/7/76
-122.045	38.9517	300	9/7/76
-121.650	39.5111	20	9/7/76
-121.613	39.4947	390	9/7/76
-121.595	39.3756	60	9/2/76
-121.519	39.4083	20	9/2/76
-121.671	39.3650	20	9/2/76
-121.581	39.4433	360	9/2/76
-121.706	39.3192	20	9/1/76
-121.787	39.4189	20	9/1/76
-121.757	39.3686	30	9/1/76
-121.692	39.3667	20	9/1/76
-121.793	39.2911	30	9/1/76
-121.593	39.3219	9	8/31/76
-121.645	39.3233	90	8/31/76
-121.664	39.2897	20	8/31/76
-121.603	39.3533	40	8/31/76
-121.581	39.3361	350	8/31/76
-121.562	39.3361	280	8/31/76
-121.533	39.2958	20	8/26/76
-121.370	39.3369	9	8/26/76
-121.413	39.3308	50	8/26/76
-121.407	39.3125	9	8/26/76
-121.495	39.2939	20	8/26/76
-121.388	39.3281	250	8/26/76
-121.596	39.2567	20	8/25/76
-121.558	39.2353	40	8/25/76
-121.453	39.2297	7	8/25/76
-121.453	39.2261	2	8/25/76
-121.481	39.2172	20	8/25/76
-121.689	39.2578	30	8/24/76
-121.884	39.2742	30	8/24/76
-121.890	39.2539	20	8/24/76
-121.781	39.1503	70	8/19/76
-121.715	39.1878	20	8/18/76
-121.620	39.1486	310	8/18/76
-121.688	39.1211	30	8/18/76
-121.643	39.1003	70	8/18/76
-121.570	39.1628	7	8/17/76
-121.572	39.1178	7	8/17/76
-121.373	39.0744	9	8/16/76
-121.465	39.1292	20	8/16/76

-121.536	39.0789	30	8/12/76
-121.492	39.0183	40	8/12/76
-121.555	39.0222	20	8/12/76
-121.633	39.0167	150	8/11/76
-121.671	39.0981	50	8/11/76
-121.609	39.0103	100	8/10/76
-121.672	39.0011	130	8/10/76
-121.688	38.8000	320	8/10/76
-121.679	38.9281	280	8/10/76
-121.794	38.9975	50	8/10/76
-121.490	38.9694	20	8/9/76
-121.403	38.9586	70	8/9/76
-121.523	38.9453	20	8/9/76
-121.436	38.9406	20	8/9/76
-121.470	38.9933	160	8/9/76
-121.466	38.9353	7	8/9/76
-121.577	39.0033	20	8/9/76
-121.567	38.9283	190	8/9/76
-121.403	38.9586	70	8/9/76
-121.487	38.9328	20	8/9/76
-121.402	38.8458	30	8/5/76
-121.451	38.9139	70	8/5/76
-121.400	38.8967	140	8/5/76
-121.433	38.8911	50	8/5/76
-121.402	38.8458	30	8/5/76
-121.433	38.8911	50	8/5/76
-121.400	38.8967	140	8/5/76
-121.451	38.9139	70	8/5/76
-121.451	38.9750	30	8/5/76
-121.486	38.8717	60	8/4/76
-121.577	38.8922	30	8/4/76
-121.566	38.9153	100	8/4/76
-121.605	38.8753	350	8/4/76
-121.593	38.8653	60	8/4/76
-121.450	38.8031	90	8/3/76
-121.407	38.7558	170	8/3/76
-121.450	38.8031	90	8/3/76
-121.488	38.8389	60	8/3/76
-121.407	38.7558	170	8/3/76
-121.494	38.7581	180	8/3/76
-121.590	38.7569	410	8/2/76
-121.534	38.8089	120	8/2/76
-121.617	38.8019	130	8/2/76
-122.038	39.4436	200	7/27/76
-121.486	38.8717	20	6/11/76
-121.879	38.4017	20	6/8/76
-122.187	40.1842	1500	6/3/76
-122.167	39.8092	200	6/1/76
-122.199	40.2561	2100	5/24/76
-121.926	39.9122	20	10/21/75
-122.074	39.9103	160	10/21/75
-121.921	39.9128	20	10/21/75
-122.054	39.9350	150	10/21/75
-121.919	39.9131	20	10/21/75
-122.012	39.9581	140	10/21/75
-122.101	40.0339	390	10/21/75
-122.092	40.0483	420	10/21/75
-122.055	39.9258	110	10/21/75
-122.012	39.9492	90	10/21/75
-121.895	39.8175	20	10/20/75
-121.984	39.8403	20	10/20/75
-121.908	39.8044	40	10/20/75
-121.906	39.8175	30	10/20/75
-122.020	39.8181	80	10/20/75
-121.878	39.8194	20	10/20/75
-121.880	39.8206	9	10/20/75
-121.914	39.8142	20	10/20/75
-121.913	39.8111	30	10/20/75
-121.890	39.8014	110	10/20/75
-121.903	39.7983	130	10/20/75
-121.902	39.7431	110	10/9/75
-122.078	39.4928	110	10/9/75
-121.807	39.7122	7	10/9/75
-121.867	39.7189	110	10/9/75
-121.917	39.7233	130	10/9/75
-121.889	39.7569	110	10/9/75
-121.868	39.7611	130	10/9/75
-121.824	39.7656	30	10/9/75
-121.911	39.7758	190	10/9/75
-121.897	39.7306	150	10/9/75
-121.860	39.7417	160	10/9/75
-122.008	39.6394	120	10/8/75
-122.004	39.7094	110	10/8/75
-121.955	39.7808	30	10/8/75
-121.981	39.7811	20	10/8/75
-121.935	39.7964	50	10/8/75
-122.002	39.7578	130	10/8/75
-122.004	39.6664	160	10/8/75
-121.956	39.7919	20	10/8/75
-121.958	39.7794	20	10/8/75
-122.025	39.6558	120	10/8/75
-121.901	39.6958	110	10/7/75
-122.004	39.5447	200	10/7/75
-121.816	39.6992	40	10/7/75
-121.851	39.6697	50	10/7/75
-121.804	39.6489	30	10/7/75
-121.814	39.6244	30	10/7/75
-121.859	39.6831	40	10/7/75
-121.812	39.7050	40	10/7/75
-122.031	39.5831	100	10/2/75
-122.044	39.5725	160	10/2/75
-122.031	39.4572	170	10/1/75
-122.051	39.4572	160	10/1/75
-122.073	39.4578	110	10/1/75
-122.120	39.2956	420	10/1/75
-122.016	39.5108	110	10/1/75
-122.037	39.4942	180	10/1/75
-122.012	39.5228	150	10/1/75
-122.051	39.4811	120	10/1/75
-122.050	39.4811	130	10/1/75
-122.026	39.5003	90	10/1/75
-121.803	39.4381	20	9/30/75
-122.017	39.4622	100	9/30/75
-121.988	39.4639	120	9/30/75
-122.019	39.4700	290	9/30/75
-121.979	39.4761	100	9/30/75
-121.852	39.4203	40	9/30/75
-121.964	39.4925	140	9/30/75
-122.019	39.4944	130	9/30/75
-121.977	39.5222	130	9/30/75
-121.816	39.4203	20	9/30/75
-122.019	39.4353	130	9/26/75
-121.953	39.4197	90	9/26/75
-121.960	39.3942	70	9/26/75
-122.028	39.4353	150	9/26/75
-122.050	39.4222	60	9/26/75
-121.969	39.4150	220	9/26/75
-121.977	39.4450	100	9/26/75
-122.040	39.4500	230	9/26/75
-121.953	39.4197	80	9/26/75
-122.110	39.3911	80	9/26/75
-122.019	39.2183	200	9/25/75
-122.035	39.2119	340	9/25/75
-122.021	39.2281	420	9/25/75
-122.049	39.2178	200	9/25/75
-122.068	39.1083	220	9/25/75
-122.004	39.1975	300	9/25/75
-122.006	39.1989	320	9/24/75
-122.011	39.2808	150	9/24/75
-122.010	39.2103	220	9/24/75
-121.992	39.2142	370	9/24/75
-122.021	39.2125	220	9/24/75
-121.935	39.1708	140	9/24/75
-121.965	39.4211	120	9/24/75
-121.993	39.3908	170	9/24/75
-122.006	39.1944	310	9/24/75
-122.010	39.1844	350	9/24/75
-121.986	39.0347	170	9/18/75
-121.950	39.0542	220	9/18/75
-122.008	39.0800	250	9/18/75
-121.999	39.1836	340	9/18/75
-122.001	39.0133	410	9/18/75
-121.914	39.1158	90	9/18/75
-121.867	39.0653	330	9/17/75
-121.861	39.0619	330	9/17/75
-121.827	39.0056	170	9/17/75
-121.838	38.9597	90	9/17/75
-121.893	39.1806	70	9/15/75
-121.831	39.0411	50	9/15/75
-121.822	39.1072	80	9/15/75
-121.823	39.1558	40	9/15/75
-121.841	39.1461	40	9/15/75
-121.903	39.1153	90	9/15/75
-121.788	38.9025	160	9/11/75
-121.774	38.8667	630	9/11/75
-121.786	38.8564	290	9/11/75
-121.710	38.8806	760	9/11/75
-121.700	38.8072	800	9/10/75
-121.793	38.8067	8100	9/10/75
-121.786	38.7936	1400	9/10/75
-122.056	39.4819	200	7/28/75
-122.068	39.7967	100	7/26/75
-121.822	39.1072	20	6/6/75
-121.562	39.1125	20	6/5/75
-122.235	39.9753	20	6/5/75
-121.588	39.1517	20	6/5/75
-121.487	39.0636	20	6/4/75
-122.133	39.1756	400	6/4/75
-122.016	38.9481	200	6/2/75
-121.662	39.3811	20	5/28/75
-122.197	40.0539	320	10/2/74
-122.162	40.0267	2	10/2/74
-122.093	39.8881	20	10/1/74
-122.087	39.8811	270	10/1/74
-122.162	40.0186	6	10/1/74
-122.130	39.8986	4	10/1/74
-122.139	39.9231	180	10/1/74
-122.106	39.9319	20	10/1/74
-122.155	39.9753	180	10/1/74
-122.173	39.9772	20	10/1/74
-122.159	40.0086	80	10/1/74
-122.176	40.0106	60	10/1/74
-122.187	40.0125	60	10/1/74
-122.164	40.0178	20	10/1/74
-122.084	39.8678	30	10/1/74
-122.103	39.8286	20	9/30/74
-122.186	39.9381	130	9/30/74
-122.104	39.7981	20	9/30/74
-122.053	39.8006	100	9/30/74
-122.088	39.8056	100	9/30/74
-122.098	39.8111	110	9/30/74
-122.070	39.8125	120	9/30/74
-122.069	39.8142	150	9/30/74
-122.188	39.9469	20	9/30/74

-122.127	39.8264	110	9/30/74
-122.065	39.8089	50	9/30/74
-122.140	39.7986	20	9/26/74
-122.159	39.8542	40	9/26/74
-122.186	39.8786	20	9/26/74
-122.196	39.8833	20	9/26/74
-122.173	39.8956	30	9/26/74
-122.192	39.9075	50	9/26/74
-122.176	39.9078	290	9/26/74
-122.148	39.9142	8	9/26/74
-122.149	39.9172	20	9/26/74
-122.148	39.8358	20	9/26/74
-122.246	39.7797	280	9/25/74
-122.152	39.7975	30	9/25/74
-122.187	39.7869	180	9/25/74
-122.241	39.7594	30	9/25/74
-122.211	39.7586	70	9/25/74
-122.167	39.7550	200	9/25/74
-122.207	39.7525	280	9/25/74
-122.233	39.7475	50	9/25/74
-122.214	39.7472	60	9/25/74
-122.189	39.7358	130	9/25/74
-122.158	39.7283	210	9/25/74
-122.174	39.7258	60	9/25/74
-122.114	39.7242	260	9/25/74
-122.104	39.7208	200	9/25/74
-122.246	39.7872	50	9/25/74
-122.106	39.7311	140	9/24/74
-122.134	39.7108	180	9/24/74
-122.121	39.7361	100	9/24/74
-122.134	39.7464	580	9/24/74
-122.107	39.7475	160	9/24/74
-122.065	39.7972	120	9/24/74
-122.133	39.7611	210	9/24/74
-122.079	39.7672	520	9/24/74
-122.122	39.7722	210	9/24/74
-122.140	39.7747	320	9/24/74
-122.110	39.7578	290	9/24/74
-122.045	39.6664	160	9/23/74
-122.253	39.6675	170	9/23/74
-122.139	39.6744	160	9/23/74
-122.148	39.6744	60	9/23/74
-122.136	39.6786	270	9/23/74
-122.122	39.6811	90	9/23/74
-122.124	39.7103	350	9/23/74
-122.122	39.7039	340	9/23/74
-122.184	39.6642	120	9/23/74
-122.129	39.6889	250	9/23/74
-122.112	39.6892	160	9/23/74
-122.149	39.6564	330	9/23/74
-122.130	39.6467	200	9/23/74
-122.228	39.6461	140	9/23/74
-122.159	39.6381	300	9/23/74
-122.191	39.6833	180	9/18/74
-122.268	39.6047	30	9/18/74
-122.143	39.6978	160	9/18/74
-122.202	39.7094	90	9/18/74
-122.144	39.7128	280	9/18/74
-122.205	39.6836	200	9/18/74
-122.195	39.6189	50	9/17/74
-122.223	39.6131	30	9/17/74
-122.216	39.5208	400	9/17/74
-122.146	39.5964	50	9/17/74
-122.203	39.5356	380	9/17/74
-122.194	39.5097	90	9/17/74
-122.211	39.5808	130	9/17/74
-122.195	39.5289	60	9/17/74
-122.206	39.5775	30	9/17/74
-122.248	39.5697	70	9/17/74
-122.154	39.5542	30	9/17/74
-122.249	39.5386	200	9/17/74
-122.147	39.5542	50	9/17/74
-122.238	39.6036	20	9/17/74
-122.210	39.4153	260	9/17/74
-122.216	39.5247	210	9/17/74
-122.227	39.2814	430	9/17/74
-122.141	39.5964	70	9/17/74
-122.220	39.5814	140	9/17/74
-122.195	39.5944	30	9/17/74
-122.224	39.5844	40	9/17/74
-122.263	39.1717	550	9/12/74
-122.273	39.1369	510	9/12/74
-122.267	39.1675	280	9/12/74
-122.262	39.1506	450	9/12/74
-122.228	39.1514	520	9/6/74
-122.141	39.1392	670	9/6/74
-122.212	39.1089	310	9/6/74
-122.153	39.1411	1300	9/6/74
-122.225	39.1403	250	9/6/74
-122.152	39.1567	510	9/6/74
-122.226	39.1594	500	9/6/74
-122.133	39.1756	400	9/6/74
-122.160	39.1486	420	9/6/74
-122.139	39.1475	430	9/6/74
-122.150	39.1169	140	9/5/74
-122.161	39.0911	150	9/5/74
-122.142	39.0933	140	9/5/74
-122.159	39.0486	260	9/5/74
-122.179	40.1947	900	9/5/74
-122.151	39.1136	270	9/5/74
-122.194	39.1158	260	9/5/74
-122.164	39.1000	340	9/5/74
-122.150	39.0719	570	9/5/74
-122.151	39.1108	400	9/5/74
-122.040	39.0494	80	9/4/74
-122.070	39.0158	880	9/4/74
-122.119	39.0125	20	9/4/74
-122.076	39.0494	60	8/30/74
-122.077	39.0642	100	8/30/74
-122.123	39.0583	20	8/30/74
-122.132	39.0567	70	8/30/74
-122.131	39.0567	120	8/30/74
-122.089	39.0803	130	8/30/74
-122.077	39.0636	70	8/30/74
-122.069	39.0958	80	8/29/74
-122.095	39.0994	260	8/29/74
-122.129	39.0853	160	8/29/74
-122.098	39.0878	140	8/29/74
-122.125	39.0969	80	8/29/74
-122.097	39.0878	160	8/29/74
-122.082	38.9536	2700	8/27/74
-122.048	38.9511	360	8/27/74
-122.063	38.9436	1300	8/27/74
-122.035	38.9261	200	8/27/74
-122.102	38.9722	70	8/23/74
-122.045	38.9517	220	8/23/74
-122.043	38.9575	330	8/23/74
-122.024	38.9664	260	8/23/74
-122.064	38.9636	580	8/23/74
-122.060	38.9764	2900	8/23/74
-122.069	38.9906	1000	8/22/74
-121.923	38.9286	330	8/21/74
-122.055	39.0125	400	8/21/74
-121.971	38.9308	120	8/21/74
-121.945	38.9317	280	8/21/74
-122.088	39.0106	20	8/21/74
-121.984	38.9256	200	8/21/74
-121.944	38.9319	310	8/21/74
-121.989	38.9350	240	8/21/74
-121.995	38.9353	100	8/21/74
-122.026	39.0050	850	8/21/74
-122.078	39.0083	20	8/21/74
-121.989	38.9611	140	8/20/74
-122.015	38.9264	290	8/20/74
-121.978	38.9550	20	8/20/74
-121.952	38.9539	410	8/20/74
-121.987	38.9486	330	8/20/74
-122.022	38.9481	140	8/20/74
-122.016	38.9481	160	8/20/74
-121.969	38.9589	320	8/20/74
-122.074	38.9253	590	8/20/74
-122.020	38.9622	170	8/20/74
-121.998	38.9403	60	8/20/74
-121.969	38.9422	260	8/20/74
-121.830	38.5472	200	8/14/74
-121.961	38.9700	110	8/13/74
-121.662	38.5533	600	8/13/74
-122.031	38.9222	120	8/13/74
-122.007	38.9992	510	8/13/74
-121.997	38.9983	460	8/13/74
-121.999	38.9769	160	8/13/74
-121.984	38.9706	230	8/13/74
-121.978	38.8639	370	8/9/74
-121.922	38.8411	510	8/9/74
-121.943	38.8675	130	8/9/74
-121.982	38.8911	250	8/9/74
-121.989	38.8881	970	8/9/74
-121.977	38.8819	90	8/9/74
-121.971	38.8817	280	8/9/74
-121.956	38.8747	320	8/9/74
-121.968	38.8872	250	8/9/74
-121.903	38.8247	530	8/8/74
-121.538	38.5781	1500	8/8/74
-121.982	38.9039	400	8/8/74
-121.991	38.9094	80	8/8/74
-121.986	38.9186	240	8/8/74
-122.023	38.9144	170	8/8/74
-121.992	38.9144	660	8/8/74
-121.922	38.8311	530	8/7/74
-121.906	38.8164	290	8/7/74
-121.901	38.8164	660	8/7/74
-121.883	38.7981	1100	8/7/74
-121.969	39.4150	200	7/11/74
-121.468	39.1294	20	7/2/74
-121.466	39.0667	20	7/1/74
-122.155	40.0628	20	6/10/74
-122.232	39.9169	20	6/7/74
-121.997	38.9983	500	6/3/74
-122.152	39.0808	100	5/31/74
-121.923	38.9286	300	5/30/74
-121.987	39.2069	200	5/29/74
-121.883	39.6906	20	5/23/74
-121.944	39.6364	20	5/22/74
-122.199	40.2561	200	8/22/73
-122.079	39.6753	20	7/23/73
-122.038	39.4436	100	7/19/73
-122.276	39.6128	20	7/18/73
-122.164	39.6992	100	7/18/73
-122.031	39.2167	200	7/13/73
-121.997	38.9983	400	7/12/73
-122.008	39.3497	100	7/10/73
-122.104	40.1233	100	6/29/73
-122.102	40.0728	200	6/29/73
-122.235	39.9753	20	6/27/73

-122.179	40.1947	1000	6/25/73
-121.814	39.6244	20	6/15/73
-122.097	39.0342	20	5/10/73
-122.157	39.0575	100	5/10/73
-122.276	39.6128	20	5/10/73
-122.187	39.2772	200	3/28/73
-121.890	38.8197	400	8/30/72
-122.031	39.2167	300	8/27/72
-121.932	38.3978	0	8/23/72
-122.051	39.0158	500	8/22/72
-122.152	39.0808	0	8/22/72
-122.157	39.0575	200	8/22/72
-121.768	38.5736	900	8/16/72
-121.903	38.8247	500	8/15/72
-121.940	38.7378	500	8/15/72
-121.974	38.4178	0	8/14/72
-121.548	38.4150	1700	8/14/72
-122.185	39.8258	100	8/14/72
-121.543	38.5339	1800	8/14/72
-122.004	39.7397	200	7/26/72
-122.179	40.1947	1200	7/20/72
-122.120	39.5361	0	6/28/72
-122.042	38.7442	100	8/18/71
-121.671	38.6719	1900	8/13/71
-121.489	38.7556	200	8/13/71
-121.913	39.1444	100	8/12/71
-121.884	39.2742	0	8/11/71
-121.398	38.9231	100	8/5/71
-121.398	38.9231	100	8/5/71
-121.372	38.5839	0	8/4/71
-121.741	38.4156	0	8/3/71
-122.187	40.1842	1100	7/29/71
-122.013	39.5222	100	7/28/71
-122.008	39.6394	100	7/28/71
-122.279	39.4475	0	7/14/71
-122.004	39.7397	100	7/14/71
-122.031	39.5831	0	7/14/71
-122.038	39.4436	100	7/14/71
-122.068	39.7967	100	7/12/71
-122.131	40.0347	0	7/8/71
-122.155	40.0633	0	7/7/71
-122.149	40.0597	0	7/7/71
-121.984	39.8617	0	6/29/71
-122.151	39.0858	200	6/23/71
-122.016	39.2281	200	6/22/71
-122.120	39.2956	200	6/21/71
-122.133	39.1756	400	6/21/71
-121.883	39.6906	0	6/20/71
-121.861	39.0619	400	9/11/70
-122.133	39.1756	500	9/10/70
-122.016	38.9481	300	9/10/70
-121.940	38.7378	600	9/10/70
-122.008	38.9983	500	9/10/70
-122.011	38.9989	700	9/10/70
-122.120	39.2956	400	9/4/70
-121.903	38.8247	500	9/4/70
-122.227	39.2814	200	9/4/70
-121.987	39.2069	200	9/3/70
-121.548	38.4150	1700	9/3/70
-121.543	38.5339	1600	9/3/70
-121.535	39.3272	0	9/2/70
-121.662	39.3811	0	9/2/70
-121.823	39.1558	0	9/1/70
-121.814	39.6244	0	8/31/70
-121.883	39.6906	0	8/31/70
-121.466	39.0667	0	8/30/70
-121.555	39.1869	0	8/17/70
-121.510	39.2144	0	8/17/70
-121.559	39.0514	0	8/14/70
-121.493	39.1308	0	8/14/70
-121.470	38.9933	200	8/13/70
-121.402	38.8458	0	8/11/70
-121.402	38.8458	0	8/11/70
-121.497	38.6828	0	8/10/70
-121.468	38.5244	0	8/7/70
-121.334	38.4433	0	8/6/70
-121.969	39.4150	200	7/30/70
-122.166	39.4667	200	7/30/70
-122.013	39.5222	100	7/30/70
-122.008	39.6394	100	7/30/70
-122.068	39.7964	0	7/29/70
-122.164	39.6992	100	7/29/70
-122.102	40.0728	0	7/14/70
-122.131	40.0347	0	7/3/70
-122.155	40.0628	0	7/3/70
-122.191	40.0453	0	7/3/70
-122.054	39.9339	400	6/5/70
-122.104	39.8833	300	6/4/70
-122.187	40.1842	1200	6/3/70

Lead Dissolved (µg/L as Pb)

Longitude	Latitude	Result	Date
-122.288	39.0125	5	9/19/86
-122.281	39.0222	5	9/19/86
-122.279	39.0233	5	9/19/86
-121.403	38.6167	9	9/29/82
-121.305	38.2628	4	9/22/82
-121.309	38.7050	1	9/17/82
-121.341	38.6700	1	9/16/82
-122.068	38.7092	5	9/3/81
-121.515	38.5411	1	8/27/81
-121.756	38.5319	0	8/26/81
-121.911	38.5906	7	8/20/81
-121.869	38.6642	2	8/13/81
-121.931	38.3247	1	9/16/80
-121.953	38.4039	4	9/12/80
-121.693	38.5644	2	8/1/79
-121.674	38.5631	0	8/1/79
-121.683	38.5822	0	8/1/79
-121.933	38.5967	0	7/31/79
-121.759	38.6122	0	7/31/79
-121.780	38.5961	0	7/31/79
-121.904	38.5728	0	7/31/79
-121.804	38.5475	2	7/31/79
-121.821	38.5836	0	7/31/79
-121.885	38.5472	0	7/26/79
-121.982	38.6908	0	7/26/79
-121.845	38.5300	2	7/26/79
-121.823	38.6911	0	7/26/79
-121.932	38.8372	0	7/25/79
-121.947	38.7158	0	7/25/79
-121.824	38.7647	0	7/25/79
-121.802	38.7433	0	6/7/79
-122.017	38.8061	0	6/7/79
-121.885	38.8161	0	6/7/79
-121.969	38.5808	0	6/6/79
-121.950	38.6419	0	6/6/79
-121.982	38.6908	0	6/6/79
-121.988	38.7442	0	6/6/79
-122.007	38.7233	0	6/6/79
-121.756	38.6397	0	6/5/79
-121.802	38.6225	0	6/5/79
-121.821	38.5836	0	6/5/79
-121.729	38.7200	0	6/5/79
-121.736	38.6625	0	6/5/79
-121.734	38.6081	0	6/4/79
-121.767	38.5800	0	6/4/79
-121.703	38.5317	0	6/4/79
-121.711	39.5492	2	9/8/76
-121.413	39.3308	0	8/26/76
-121.536	39.0789	0	8/12/76
-121.403	38.9586	2	8/9/76
-121.403	38.9586	2	8/9/76
-121.774	38.8667	3	9/11/75
-121.562	39.1125	0	6/5/75
-122.235	39.9753	0	6/5/75
-122.133	39.1756	0	6/4/75
-122.016	38.9481	0	6/2/75
-122.162	40.0186	3	10/1/74
-122.194	39.5097	2	9/17/74
-122.159	39.0486	4	9/5/74
-122.125	39.0969	0	8/29/74
-121.946	38.3514	0	7/10/74
-122.187	39.2772	20	5/31/74

Solids, Sum of Constituents, Dissolved (mg/L)

Longitude	Latitude	Result	Date
-122.294	39.7822	307	7/26/75
-122.288	39.0125	870	9/19/86
-122.281	39.0222	1200	9/19/86
-122.279	39.0233	1000	9/19/86
-122.279	39.4475	767	7/14/71
-122.276	39.6128	221	7/18/73
-122.273	39.1369	822	9/12/74
-122.267	39.1675	460	9/12/74
-122.263	39.1717	463	9/12/74
-122.262	39.1506	917	9/12/74
-122.238	39.6036	221	9/17/74
-122.235	39.9753	407	6/5/75
-122.235	39.9753	310	6/27/73
-122.228	39.1514	565	9/6/74
-122.227	39.2814	341	9/4/70
-122.226	39.1594	568	9/6/74
-122.225	39.1403	443	9/6/74
-122.212	39.1089	450	9/6/74
-122.211	39.5808	299	9/17/74
-122.210	39.4153	423	9/17/74
-122.207	39.7525	309	9/25/74
-122.202	39.7094	299	9/18/74
-122.199	40.2561	389	5/24/76
-122.199	40.2561	284	8/22/73
-122.198	38.8108	771	8/17/81
-122.195	39.6189	202	9/17/74
-122.194	39.1158	398	9/5/74
-122.192	39.9075	141	9/26/74
-122.191	40.0453	216	7/3/70
-122.187	40.1842	312	6/3/76
-122.187	40.1842	307	7/29/71
-122.187	40.1842	266	6/3/70
-122.187	39.2772	578	3/28/73
-122.179	40.1947	398	9/5/74
-122.179	40.1947	444	6/25/73
-122.179	40.1947	330	7/20/72
-122.176	39.9078	147	9/26/74
-122.167	39.8092	217	6/1/76
-122.166	39.4667	394	7/30/70
-122.164	39.1000	384	9/5/74
-122.164	39.6992	410	7/18/73
-122.164	39.6992	378	7/29/70

-122.164	40.0178	219	10/1/74
-122.162	40.0186	208	10/1/74
-122.161	39.0911	322	9/5/74
-122.160	39.1486	569	9/6/74
-122.159	39.0486	598	9/5/74
-122.157	39.0575	352	5/10/73
-122.157	39.0575	538	8/22/72
-122.155	40.0633	222	7/7/71
-122.155	40.0628	310	6/10/74
-122.155	40.0628	216	7/3/70
-122.153	39.1411	348	9/6/74
-122.152	39.0808	321	5/31/74
-122.152	39.1567	781	9/6/74
-122.151	39.1108	450	9/5/74
-122.151	39.1136	470	9/5/74
-122.151	39.0858	340	6/23/71
-122.150	39.0719	268	9/5/74
-122.150	39.1169	320	9/5/74
-122.149	40.0597	212	7/7/71
-122.142	39.0933	310	9/5/74
-122.141	39.1392	599	9/6/74
-122.139	39.1475	574	9/6/74
-122.134	39.7464	327	9/24/74
-122.133	39.1756	622	6/4/75
-122.133	39.1756	634	9/6/74
-122.133	39.1756	603	6/21/71
-122.133	39.1756	612	9/10/70
-122.132	39.0567	285	8/30/74
-122.131	39.0567	233	8/30/74
-122.131	40.0347	399	7/8/71
-122.131	40.0347	380	7/3/70
-122.129	39.0853	287	8/29/74
-122.126	39.4292	358	8/3/77
-122.125	39.0969	378	8/29/74
-122.124	39.7103	297	9/23/74
-122.123	39.0583	114	8/30/74
-122.122	39.7039	348	9/23/74
-122.120	39.2956	1170	10/1/75
-122.120	39.2956	1130	6/21/71
-122.120	39.2956	1130	9/4/70
-122.120	39.5361	172	6/28/72
-122.119	39.0125	229	9/4/74
-122.110	39.3911	189	9/26/75
-122.106	39.9319	221	10/1/74
-122.104	39.8833	187	6/4/70
-122.102	38.9722	279	8/23/74
-122.102	40.0728	206	7/14/70
-122.098	39.0878	269	8/29/74
-122.097	39.0342	158	5/10/73
-122.097	39.0878	346	8/29/74
-122.095	39.0994	309	8/29/74
-122.089	39.0803	245	8/30/74
-122.088	39.0106	302	8/21/74
-122.084	39.8678	241	10/1/74
-122.082	38.9536	506	8/27/74
-122.079	39.7672	307	9/24/74
-122.079	39.6753	380	7/23/73
-122.078	39.0083	226	8/21/74
-122.077	39.0642	211	8/30/74
-122.077	39.0636	216	8/30/74
-122.076	39.0494	161	8/30/74
-122.074	38.9253	344	8/20/74
-122.074	39.9103	347	10/21/75
-122.073	39.4578	205	10/1/75
-122.070	39.0158	455	9/4/74
-122.070	39.8125	283	9/30/74
-122.069	38.9906	366	8/22/74
-122.069	39.0958	444	8/29/74
-122.069	39.8142	243	9/30/74
-122.068	38.7092	631	9/3/81
-122.068	39.1083	437	9/25/75
-122.068	39.7964	350	7/29/70
-122.068	39.7967	386	7/26/75
-122.068	39.7967	349	7/12/71
-122.065	39.8089	281	9/30/74
-122.064	38.9636	446	8/23/74
-122.063	38.9436	401	8/27/74
-122.060	38.9764	615	8/23/74
-122.059	38.7597	436	8/10/81
-122.056	39.4819	590	7/28/75
-122.055	39.0125	295	8/21/74
-122.054	39.9350	233	10/21/75
-122.054	39.9339	263	6/5/70
-122.053	38.7597	301	9/2/81
-122.051	39.4572	379	10/1/75
-122.051	39.4811	444	10/1/75
-122.051	38.9200	361	8/27/74
-122.048	38.9511	413	8/27/74
-122.045	38.9517	386	9/7/76
-122.045	38.9517	407	8/23/74
-122.043	38.9575	390	8/23/74
-122.042	38.7442	270	8/18/71
-122.040	39.4500	599	9/26/75
-122.040	39.0494	232	9/4/74
-122.038	39.4436	461	7/27/76
-122.038	39.4436	198	7/19/73
-122.038	39.4436	437	7/14/71
-122.037	39.4942	391	10/1/75
-122.036	38.6928	287	6/6/79
-122.035	38.9261	300	8/27/74
-122.033	38.8161	345	9/2/81
-122.031	39.5831	257	7/14/71
-122.031	38.9222	307	8/13/74
-122.031	39.2167	517	7/13/73
-122.031	39.2167	584	8/27/72
-122.026	39.0050	435	8/21/74
-122.025	39.6558	262	10/8/75
-122.024	38.9664	301	8/23/74
-122.023	38.9150	305	7/30/81
-122.023	38.9144	290	8/8/74
-122.022	38.9481	298	8/20/74
-122.021	39.2125	346	9/24/75
-122.020	38.9622	326	8/20/74
-122.020	39.8181	210	10/20/75
-122.019	39.4944	242	9/30/75
-122.019	39.4353	284	9/26/75
-122.017	38.8061	585	9/2/81
-122.017	38.8061	402	6/7/79
-122.017	39.4622	268	9/30/75
-122.016	38.9481	252	6/2/75
-122.016	38.9481	247	8/20/74
-122.016	38.9481	232	9/10/70
-122.016	38.7442	372	8/19/81
-122.016	39.2281	249	6/22/71
-122.015	38.9264	374	8/20/74
-122.013	39.5222	160	7/28/71
-122.013	39.5222	212	7/30/70
-122.012	39.5228	297	10/1/75
-122.011	38.9989	777	9/7/76
-122.011	38.9989	893	9/10/70
-122.011	39.2808	409	9/24/75
-122.010	39.1844	1750	9/24/75
-122.010	39.2103	331	9/24/75
-122.008	38.9983	1040	9/10/70
-122.008	39.0800	806	9/18/75
-122.008	39.3497	204	7/10/73
-122.008	39.6394	244	10/8/75
-122.008	39.6394	213	7/28/71
-122.008	39.6394	209	7/30/70
-122.007	38.7233	318	7/25/79
-122.007	38.7233	319	6/6/79
-122.007	38.9992	735	8/13/74
-122.006	39.1989	525	9/24/75
-122.004	39.7397	225	7/27/76
-122.004	39.7397	335	7/18/73
-122.004	39.7397	333	7/26/72
-122.004	39.7397	314	7/14/71
-122.004	39.1975	400	9/25/75
-121.999	38.9769	353	8/13/74
-121.998	38.5292	272	8/28/81
-121.998	38.7389	350	6/6/79
-121.998	38.9403	257	8/20/74
-121.997	38.3411	714	9/12/80
-121.997	38.9983	847	8/13/74
-121.997	38.9983	771	6/3/74
-121.997	38.9983	1120	7/12/73
-121.995	38.9353	282	8/21/74
-121.992	38.9144	302	8/8/74
-121.991	38.9094	288	8/8/74
-121.989	38.8881	288	8/9/74
-121.989	38.9350	345	8/21/74
-121.989	38.9611	261	8/20/74
-121.988	38.6083	380	9/8/81
-121.988	38.7442	324	6/6/79
-121.987	38.9486	223	8/20/74
-121.987	39.2069	223	9/8/76
-121.987	39.2069	273	5/29/74
-121.987	39.2069	238	9/3/70
-121.986	38.9186	241	8/8/74
-121.986	39.0347	228	9/18/75
-121.984	38.9256	210	8/21/74
-121.984	38.9706	282	8/13/74
-121.984	39.8617	386	6/29/71
-121.984	39.8403	232	10/20/75
-121.983	38.4975	328	8/26/80
-121.982	38.8911	206	8/9/74
-121.982	38.6908	624	7/26/79
-121.982	38.6908	482	6/6/79
-121.982	38.9039	322	8/8/74
-121.981	38.6703	514	6/6/79
-121.981	39.7811	300	10/8/75
-121.979	39.4761	264	9/30/75
-121.978	38.9550	222	8/20/74
-121.978	38.8639	333	8/9/74
-121.977	39.4450	280	9/26/75
-121.977	38.8819	250	8/9/74
-121.974	38.4178	240	8/14/72
-121.972	38.5600	437	8/28/81
-121.971	38.8817	245	8/9/74
-121.971	38.9308	252	8/21/74
-121.969	38.5808	427	6/6/79
-121.969	38.9422	250	8/20/74
-121.969	38.9589	290	8/20/74
-121.969	39.4150	258	7/11/74
-121.969	39.4150	247	7/30/70
-121.968	38.8872	248	8/9/74
-121.966	38.4425	255	9/10/80
-121.965	39.4211	405	9/24/75
-121.961	38.6306	477	7/26/79
-121.961	38.6306	483	6/6/79
-121.961	38.9700	335	8/13/74
-121.958	39.7794	286	10/8/75
-121.957	38.7175	605	7/25/79
-121.957	38.7175	556	6/6/79

-121.956	39.7919	430	10/8/75
-121.956	38.8747	233	8/9/74
-121.953	38.4039	282	9/12/80
-121.953	39.4197	291	9/26/75
-121.952	38.9539	331	8/20/74
-121.950	38.6419	401	6/6/79
-121.949	38.6675	665	9/8/81
-121.947	38.7158	655	7/25/79
-121.945	38.9317	282	8/21/74
-121.944	38.9319	277	8/21/74
-121.944	39.6364	342	5/22/74
-121.943	38.8675	320	8/9/74
-121.940	38.7378	220	9/10/70
-121.936	38.7039	484	8/19/81
-121.935	39.1708	188	9/24/75
-121.935	39.7964	292	10/8/75
-121.933	38.5967	381	7/31/79
-121.933	38.3539	451	9/3/80
-121.932	38.3978	278	8/23/72
-121.932	38.8372	348	7/25/79
-121.931	38.3247	433	9/16/80
-121.923	38.9286	312	8/21/74
-121.923	38.9286	320	5/30/74
-121.922	38.8311	402	8/7/74
-121.922	38.8411	378	8/9/74
-121.918	38.4208	561	9/10/80
-121.917	39.7233	258	10/9/75
-121.914	39.8142	253	10/20/75
-121.914	39.1158	261	9/18/75
-121.913	39.1444	290	8/12/71
-121.911	38.5906	704	8/20/81
-121.906	38.8164	325	8/7/74
-121.906	39.8175	159	10/20/75
-121.904	38.5728	642	7/31/79
-121.903	38.8247	381	8/8/74
-121.903	38.8247	461	9/4/70
-121.903	39.1153	220	9/15/75
-121.902	39.7431	192	10/9/75
-121.901	39.6958	594	10/7/75
-121.897	38.4508	302	8/26/80
-121.893	38.3225	600	9/4/80
-121.893	39.1806	244	9/15/75
-121.890	39.2539	176	8/24/76
-121.890	38.8197	290	8/30/72
-121.889	38.4900	325	9/3/80
-121.886	38.7206	213	8/13/81
-121.885	38.5472	477	7/26/79
-121.885	38.8161	301	6/7/79
-121.884	39.2742	270	8/11/71
-121.883	39.6906	541	5/23/74
-121.883	39.6906	412	6/20/71
-121.883	39.6906	372	8/31/70
-121.883	38.7981	463	8/7/74
-121.880	39.8206	137	10/20/75
-121.879	38.4017	317	6/8/76
-121.877	38.7714	175	6/7/79
-121.869	38.6642	462	8/13/81
-121.864	38.1189	1480	9/22/80
-121.861	39.0619	371	9/17/75
-121.861	39.0619	355	9/11/70
-121.859	39.6831	257	10/7/75
-121.858	38.4206	527	9/3/80
-121.852	38.5150	318	7/26/79
-121.846	38.2233	731	9/17/80
-121.845	38.5300	310	7/26/79
-121.838	38.9597	241	9/17/75
-121.835	38.5744	468	6/5/79
-121.833	38.5506	343	8/20/81
-121.831	39.0411	98	9/15/75
-121.830	38.5472	303	8/14/74
-121.824	38.2850	514	9/11/80
-121.824	38.7647	500	7/25/79
-121.823	39.1558	129	9/15/75
-121.823	39.1558	215	9/1/70
-121.823	38.6911	424	7/26/79
-121.822	39.1072	326	6/6/75
-121.821	38.5836	495	7/31/79
-121.821	38.5836	517	6/5/79
-121.820	38.7431	402	6/7/79
-121.816	39.6992	194	10/7/75
-121.814	39.6244	261	10/7/75
-121.814	39.6244	492	6/15/73
-121.814	39.6244	413	8/31/70
-121.808	38.2467	759	9/11/80
-121.808	38.6781	604	8/10/81
-121.804	39.6489	174	10/7/75
-121.804	38.1586	684	9/17/80
-121.804	38.4214	494	8/28/80
-121.804	38.5475	335	7/31/79
-121.804	38.5475	320	6/4/79
-121.804	38.1864	565	9/17/80
-121.803	39.4381	528	9/30/75
-121.803	38.3367	434	9/2/80
-121.802	38.6225	460	7/31/79
-121.802	38.6225	521	6/5/79
-121.802	38.7433	548	6/7/79
-121.799	38.5461	687	8/24/81
-121.795	39.6639	157	9/9/76
-121.794	38.9975	145	8/10/76
-121.793	38.8067	1420	9/10/75
-121.787	39.4189	219	9/1/76
-121.786	38.7936	323	9/10/75
-121.786	38.8564	268	9/11/75
-121.785	38.6414	586	8/12/81
-121.780	38.5961	471	7/31/79
-121.779	38.7431	800	6/6/79
-121.774	38.8667	442	9/11/75
-121.773	38.6550	407	6/5/79
-121.772	38.5736	588	6/4/79
-121.768	38.5736	448	8/16/72
-121.767	38.5800	508	6/4/79
-121.765	38.6869	475	8/11/81
-121.765	38.5839	502	7/31/79
-121.765	38.5839	535	6/4/79
-121.764	39.7033	173	9/9/76
-121.762	39.6708	145	9/9/76
-121.761	38.6631	441	8/11/81
-121.759	38.6122	475	7/31/79
-121.756	38.6397	449	6/5/79
-121.756	38.5319	350	8/26/81
-121.745	38.7422	440	7/25/79
-121.744	39.5942	76	9/8/76
-121.741	38.4156	237	8/3/71
-121.736	38.6625	408	6/5/79
-121.734	38.6081	822	6/4/79
-121.729	38.6181	459	8/12/81
-121.729	38.7200	532	7/25/79
-121.729	38.7200	523	6/5/79
-121.729	38.6625	583	8/11/81
-121.727	38.5828	581	8/12/81
-121.726	38.6533	653	6/4/79
-121.725	38.4594	506	8/27/80
-121.723	38.6272	367	6/5/79
-121.722	38.4869	722	8/27/80
-121.722	38.6844	365	7/25/79
-121.722	38.6844	380	6/5/79
-121.720	38.5028	459	8/25/80
-121.714	38.1986	317	9/17/80
-121.712	38.3575	1500	9/3/80
-121.711	39.5492	177	9/8/76
-121.710	38.6000	398	8/12/81
-121.710	38.8806	1170	9/11/75
-121.704	38.1597	257	9/23/80
-121.703	38.5317	1090	6/4/79
-121.699	39.4594	173	9/8/76
-121.698	38.5392	731	8/17/71
-121.694	38.5206	644	8/26/81
-121.693	38.4011	534	9/2/80
-121.693	38.5567	718	8/25/81
-121.693	38.5644	711	8/1/79
-121.693	38.5644	736	6/4/79
-121.689	39.2578	252	8/24/76
-121.688	38.8000	190	8/10/76
-121.686	38.5022	509	8/26/81
-121.686	39.5519	161	9/9/76
-121.683	38.5822	434	8/1/79
-121.674	38.5631	744	8/1/79
-121.674	38.5819	415	8/1/79
-121.672	39.0011	1570	8/10/76
-121.671	38.6719	333	8/13/71
-121.668	39.6092	180	9/8/76
-121.662	38.5533	479	8/13/74
-121.662	39.3811	169	5/28/75
-121.662	39.3811	157	9/2/70
-121.651	38.5753	560	8/26/81
-121.645	39.5561	182	9/9/76
-121.645	39.3233	723	8/31/76
-121.644	38.5089	621	8/26/81
-121.643	39.1003	524	8/18/76
-121.633	39.0167	303	8/11/76
-121.618	38.6458	819	9/1/81
-121.617	38.8019	521	8/2/76
-121.613	39.4947	178	9/7/76
-121.613	38.7083	539	9/30/82
-121.605	38.8753	1360	8/4/76
-121.603	38.1633	165	9/17/82
-121.588	39.1517	254	6/5/75
-121.583	39.4631	231	9/7/76
-121.581	39.3361	262	8/31/76
-121.581	38.5342	385	8/27/81
-121.581	39.4433	196	9/2/76
-121.577	38.8922	262	8/4/76
-121.572	39.1178	685	8/17/76
-121.570	39.1628	210	8/17/76
-121.567	38.9283	549	8/9/76
-121.563	38.6186	137	9/1/81
-121.562	39.1125	183	7/14/76
-121.562	39.1125	173	6/5/75
-121.562	39.1125	171	7/2/74
-121.559	39.0514	152	8/14/70
-121.558	38.3708	439	8/31/81
-121.556	38.5117	330	8/27/81
-121.555	39.1869	180	8/17/70
-121.548	38.4150	1660	9/3/70
-121.548	38.6011	176	9/10/82
-121.546	38.5464	629	8/27/81
-121.543	38.5339	601	9/3/70
-121.538	38.5781	1280	8/8/74
-121.536	39.0789	187	8/12/76
-121.535	39.3272	198	9/2/70
-121.533	39.2958	161	8/26/76
-121.533	38.2828	160	9/20/82
-121.523	38.3611	186	8/31/81
-121.515	38.5411	224	8/27/81

-121.510	39.2144	142	8/17/70
-121.497	38.6828	192	8/10/70
-121.493	39.1308	137	7/2/74
-121.493	39.1308	97	8/14/70
-121.492	39.0183	276	8/12/76
-121.489	38.7556	194	8/13/71
-121.488	38.8389	218	8/3/76
-121.487	39.0636	174	6/4/75
-121.486	38.8717	221	8/4/76
-121.486	38.8717	242	6/11/76
-121.481	39.2172	201	8/25/76
-121.470	38.9933	586	8/9/76
-121.470	38.9933	530	8/13/70
-121.468	39.1294	198	9/5/74
-121.468	39.1294	179	7/2/74
-121.468	39.1375	197	11/7/75
-121.468	38.5244	161	8/7/70
-121.466	39.0667	165	7/1/74
-121.466	39.0667	115	8/30/70
-121.466	38.9353	184	8/9/76
-121.465	39.1403	147	11/7/75
-121.465	38.5097	244	9/28/82
-121.464	39.1339	146	11/13/75
-121.460	38.9872	462	7/25/70
-121.458	38.5233	252	9/28/82
-121.453	39.2261	150	8/25/76
-121.451	38.9139	187	8/5/76
-121.451	38.9139	187	8/5/76
-121.450	38.8031	172	8/3/76
-121.450	38.8031	172	8/3/76
-121.413	39.3308	360	8/26/76
-121.403	38.9586	180	8/9/76
-121.403	38.9586	180	8/9/76
-121.402	38.8458	203	8/5/76
-121.402	38.8458	203	8/5/76
-121.402	38.8458	164	8/11/70
-121.402	38.8458	164	8/11/70
-121.400	38.8967	192	8/5/76
-121.400	38.8967	192	8/5/76
-121.398	38.9231	148	8/5/71
-121.398	38.9231	148	8/5/71
-121.388	39.3281	448	8/26/76
-121.385	38.6581	319	9/21/82
-121.382	38.6647	226	9/21/82
-121.374	38.9822	266	9/7/82
-121.374	38.9822	266	9/7/82
-121.373	39.0744	177	8/16/76
-121.372	38.5839	165	8/4/71
-121.369	38.6414	249	9/29/82
-121.358	38.6006	162	9/29/82
-121.337	38.8728	222	9/9/82
-121.337	38.8728	222	9/9/82
-121.334	38.4433	146	8/6/70
-121.332	38.6183	173	9/27/82
-121.332	38.6739	302	9/17/82
-121.327	38.2411	350	9/15/82
-121.309	38.7050	301	9/17/82
-121.291	38.5964	285	9/23/82
-121.284	38.6842	228	9/17/82
-121.276	39.0158	160	9/24/82
-121.276	39.0158	160	9/24/82
-121.264	38.8858	501	9/9/82
-121.264	38.8858	501	9/9/82

San Joaquin Valley

Arsenic Dissolved (µg/L as As)

Longitude	Latitude	Result	Date
-121.548	37.8017	6	6/6/79
-121.548	37.8017	6	6/6/79
-121.499	37.7589	5	5/5/84
-121.499	37.7589	5	5/5/84
-121.435	37.7961	3	6/6/79
-121.435	37.7961	3	6/6/79
-121.432	37.7792	5	5/5/84
-121.432	37.7792	5	5/5/84
-121.400	37.7244	1	5/23/79
-121.400	37.7244	1	5/23/79
-121.398	38.2083	15	5/17/78
-121.398	38.2083	15	5/17/78
-121.361	37.6864	1	6/12/79
-121.361	37.6864	1	6/12/79
-121.361	37.6458	1	6/13/79
-121.361	37.6458	1	6/13/79
-121.360	37.6933	1	3/11/85
-121.360	37.6933	1	3/11/85
-121.352	38.1547	26	5/18/78
-121.352	38.1547	26	5/18/78
-121.341	38.0319	12	6/14/78
-121.341	38.0319	12	6/14/78
-121.339	38.1181	12	6/1/78
-121.339	38.1181	12	6/1/78
-121.333	37.6011	1	6/14/79
-121.333	37.6011	1	6/14/79
-121.322	37.5992	1	3/13/85
-121.311	37.7139	1	5/14/84
-121.311	37.7139	1	5/14/84
-121.305	38.1272	10	5/31/78
-121.305	38.1272	10	5/31/78
-121.261	37.9392	10	7/22/70
-121.261	37.9392	10	7/22/70
-121.248	38.0317	2	6/14/78
-121.248	38.0317	2	6/14/78
-121.246	37.9214	11	5/8/79
-121.246	37.9214	11	5/8/79
-121.243	38.1339	1	6/6/78
-121.243	38.1339	1	6/6/78
-121.232	37.6281	1	5/5/84
-121.215	37.9319	15	6/29/78
-121.215	37.9319	15	6/29/78
-121.215	37.6150	1	5/6/84
-121.213	37.9800	4	6/22/78
-121.213	37.9800	4	6/22/78
-121.209	37.9642	11	6/29/78
-121.209	37.9642	11	6/29/78
-121.207	37.5839	18	5/6/84
-121.207	38.1878	4	5/22/78
-121.207	38.1878	4	5/22/78
-121.200	37.5494	3	3/12/85
-121.194	37.7361	8	5/17/79
-121.194	37.7361	8	5/17/79
-121.186	38.0317	2	6/14/78
-121.186	38.0317	2	6/14/78
-121.184	37.4786	1	5/16/85
-121.174	37.7989	9	5/9/79
-121.174	37.7989	9	5/9/79
-121.174	37.8647	5	5/8/79
-121.174	37.8647	5	5/8/79
-121.163	37.9914	2	6/21/78
-121.163	37.9914	2	6/21/78
-121.156	37.5433	1	5/1/85
-121.144	37.5375	1	3/13/85
-121.143	37.7400	6	5/17/79
-121.143	37.7400	6	5/17/79
-121.142	37.4361	1	5/16/85
-121.133	37.5967	2	7/2/85
-121.109	37.4561	1	4/30/85
-121.106	37.7456	1	6/19/74
-121.106	37.7456	1	6/19/74
-121.101	38.1225	5	6/7/78
-121.101	38.1225	5	6/7/78
-121.093	37.4850	1	5/5/84
-121.082	37.4550	1	5/6/84
-121.079	37.4936	5	11/17/88
-121.079	37.4653	2	5/4/84
-121.079	37.4939	1	11/17/88
-121.079	37.4908	3	4/30/85
-121.076	37.2753	3	5/7/84
-121.075	37.2897	1	5/13/85
-121.058	37.4303	1	5/5/84
-121.053	37.1881	1	5/6/84
-121.053	37.8781	3	5/9/79
-121.053	37.8781	3	5/9/79
-121.051	37.3917	1	5/7/84
-121.049	37.1881	2	5/6/84
-121.048	37.2742	1	5/7/84
-121.048	38.0267	1	6/22/78
-121.048	38.0267	1	6/22/78
-121.047	37.6044	3	5/1/85
-121.039	38.1533	2	5/25/78
-121.039	38.1533	2	5/25/78
-121.021	37.3758	2	5/7/84
-121.013	37.2322	2	5/7/84
-121.012	37.4311	40	11/16/88
-121.008	37.2275	1	5/5/84
-121.006	37.2533	1	9/12/85
-120.999	37.2425	1	3/27/85
-120.997	37.5206	6	7/18/95
-120.996	37.2533	1	9/12/85
-120.992	37.4386	1	5/15/85
-120.991	37.1883	2	5/8/84
-120.991	37.3317	1	5/7/84
-120.988	37.7989	4	5/15/79
-120.988	37.7989	4	5/15/79
-120.984	37.7981	4	5/16/79
-120.984	37.7981	4	5/16/79
-120.984	37.3558	1	5/5/84
-120.981	37.2917	1	5/5/84
-120.980	37.4342	1	5/21/85
-120.978	37.2897	3	5/7/84
-120.975	37.3508	3	11/15/88
-120.959	37.0997	5	5/7/84
-120.956	37.1453	1	3/28/85
-120.956	37.1453	1	3/28/85
-120.949	37.2842	2	5/21/84
-120.944	38.0458	2	6/27/78
-120.944	38.0458	2	6/27/78
-120.938	37.0644	15	5/6/84
-120.925	37.0817	6	5/8/84
-120.914	37.0922	7	5/6/84
-120.906	37.3539	1	6/27/85
-120.906	37.3539	1	6/19/84
-120.906	37.3539	1	7/27/83
-120.896	37.3092	1	5/13/85
-120.895	37.1139	4	4/9/85
-120.895	37.2456	1	8/9/84
-120.853	37.0522	7	9/11/85
-120.853	37.0522	7	9/11/85
-120.843	37.1000	12	4/9/85
-120.839	37.0561	9	4/11/85
-120.839	37.0561	9	4/11/85

-120.837	37.3344	38	5/14/85
-120.836	37.0125	2	5/6/84
-120.836	36.9956	1	5/5/84
-120.836	37.4286	2	6/27/85
-120.836	37.4286	2	6/19/84
-120.836	37.4286	3	7/27/83
-120.836	36.9986	1	5/9/84
-120.821	37.0997	1	8/9/84
-120.820	37.1000	2	8/9/84
-120.818	36.9542	1	5/14/84
-120.818	36.9267	2	5/15/84
-120.813	37.1600	3	4/10/85
-120.800	36.9314	1	5/14/84
-120.792	37.5442	3	7/28/94
-120.776	36.9228	1	5/15/84
-120.760	37.0786	1	5/10/84
-120.753	36.8939	1	5/21/84
-120.753	36.8939	2	5/10/84
-120.746	36.9022	1	5/10/84
-120.736	36.9044	1	5/10/84
-120.687	37.1858	6	4/10/85
-120.677	37.5889	4	5/20/87
-120.670	37.0975	3	5/10/84
-120.657	36.8067	1	5/9/84
-120.657	36.8344	1	4/11/85
-120.657	36.8344	1	4/11/85
-120.657	36.8344	1	4/11/85
-120.657	36.8344	1	4/11/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.655	36.8358	1	5/16/84
-120.653	36.8797	1	5/21/84
-120.653	36.9961	13	5/8/84
-120.643	37.3531	1	6/25/85
-120.643	37.3531	2	6/28/84
-120.643	37.3531	2	7/25/83
-120.635	37.0467	8	4/29/85
-120.632	37.4797	3	7/26/83
-120.626	37.3164	2	6/25/85
-120.626	37.3164	2	6/28/84
-120.626	37.3164	3	7/25/83
-120.626	36.8497	1	5/16/84
-120.616	36.8503	1	5/15/84
-120.616	36.9817	1	5/8/84
-120.616	37.0481	2	5/8/84
-120.616	37.0828	3	5/8/84
-120.615	37.0550	4	5/7/84
-120.600	36.8683	1	5/8/84
-120.600	37.2728	4	6/4/87
-120.599	36.9672	2	5/9/84
-120.595	37.3711	1	6/25/85
-120.595	37.3711	1	6/28/84
-120.595	37.3711	4	7/26/83
-120.588	37.3019	7	5/21/87
-120.584	36.8506	2	5/15/84
-120.584	36.9900	2	5/14/84
-120.583	36.8464	3	7/29/87
-120.583	36.8464	3	7/29/87
-120.583	36.8464	4	7/29/87
-120.583	36.8464	2	7/29/87
-120.583	36.8478	6	9/2/87
-120.583	36.8486	2	7/30/87
-120.583	36.8494	2	7/8/87
-120.583	36.9306	3	7/30/87
-120.582	37.6394	3	5/20/87
-120.580	36.8506	1	4/4/85
-120.580	36.8506	1	4/4/85
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-120.580	36.8506	2	4/4/85
-120.580	36.8506	1	4/3/85
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-120.580	36.8506	2	4/3/85
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-120.580	36.8506	1	4/3/85
-120.580	36.8506	2	4/2/85
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-120.580	36.8506	1	4/2/85
-120.580	36.8506	2	4/2/85
-120.580	36.8506	1	4/2/85
-120.571	37.0292	11	4/30/85
-120.562	36.9958	29	5/9/84
-120.557	37.0875	15	5/14/85
-120.546	36.9261	2	5/9/84
-120.533	36.8089	1	5/9/84
-120.524	36.8383	2	8/31/89
-120.524	36.8383	5	8/31/89
-120.524	36.8383	1	8/27/87
-120.524	36.8383	1	3/18/87
-120.524	36.8383	1	3/18/87
-120.524	36.8383	1	3/18/87
-120.524	36.8383	1	3/17/87
-120.524	36.8383	2	3/17/87
-120.524	36.8383	2	3/17/87
-120.524	36.8383	2	3/13/87
-120.524	36.8383	2	3/12/87
-120.524	36.8383	1	3/12/87
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-120.524	36.8383	1	3/18/85
-120.504	36.8581	1	5/15/84
-120.490	36.8947	1	5/9/84
-120.490	36.9275	11	5/9/84
-120.486	36.9064	2	11/5/85
-120.486	36.9064	1	5/15/85
-120.478	36.6322	2	3/21/86
-120.476	36.7783	1	5/16/84
-120.474	36.8211	1	5/9/84
-120.456	36.5311	7	11/5/85
-120.456	36.5311	1	3/26/85
-120.450	37.2336	6	7/20/87
-120.445	37.1492	2	7/25/83
-120.442	36.6033	1	5/18/84
-120.440	36.7194	1	5/20/84
-120.435	37.2844	4	6/26/85
-120.435	37.2844	4	6/29/84
-120.435	37.2844	6	7/26/83
-120.432	36.6542	1	8/7/84
-120.427	36.8333	1	5/15/85
-120.414	36.6467	1	8/6/84
-120.413	36.6517	2	7/1/87
-120.413	36.6517	2	6/11/87
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-120.413	36.6517	3	6/9/87
-120.413	36.6517	4	6/9/87
-120.413	36.6517	1	2/4/86
-120.413	36.6517	2	2/4/86
-120.413	36.6517	2	2/4/86
-120.413	36.6517	2	2/3/86
-120.413	36.6517	4	1/31/86
-120.413	36.6542	1	8/7/84
-120.410	36.6517	2	7/30/86
-120.410	36.6517	2	7/30/86
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-120.410	36.6517	2	2/4/86
-120.407	36.6506	2	8/14/86
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-120.407	36.6506	2	7/30/86
-120.407	36.6506	3	7/29/86
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-120.407	36.6506	2	7/17/86
-120.407	36.6506	3	7/16/86
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-120.407	36.6506	3	5/21/86
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-120.407	36.6506	3	3/6/86
-120.407	36.6506	4	3/6/86
-120.407	36.6506	3	3/6/86
-120.407	36.6506	5	3/6/86
-120.407	36.6506	2	3/6/86
-120.407	36.6506	3	3/5/86
-120.407	36.6506	2	3/5/86
-120.407	36.6506	1	3/5/86
-120.407	36.6506	1	2/28/86
-120.407	36.6506	1	2/28/86
-120.407	36.6506	2	2/27/86
-120.407	36.6506	2	2/27/86
-120.407	36.6506	1	2/27/86
-120.407	36.6506	3	2/26/86
-120.407	36.6506	4	2/26/86
-120.407	36.6506	2	2/26/86
-120.407	36.6506	4	2/26/86
-120.407	36.6506	2	2/25/86
-120.407	36.6506	3	2/11/86
-120.407	36.6506	3	2/11/86
-120.407	36.6506	1	2/11/86
-120.407	36.6506	3	2/6/86
-120.407	36.6506	3	2/6/86
-120.407	36.6506	4	2/6/86
-120.407	36.6506	2	2/6/86
-120.407	36.6506	4	2/6/86
-120.407	36.6506	2	2/6/86
-120.407	36.6506	3	2/5/86
-120.407	36.6506	2	2/5/86
-120.407	36.6506	3	2/5/86
-120.407	36.6506	1	2/5/86
-120.407	36.6506	2	2/5/86
-120.407	36.6506	2	2/4/86
-120.406	36.6542	13	10/15/87
-120.406	36.6542	2	7/31/87
-120.406	36.6542	2	6/30/87
-120.406	36.6542	1	5/7/87
-120.406	36.6542	1	4/16/87
-120.406	36.6542	1	3/27/87
-120.406	36.6542	2	9/26/86
-120.406	36.6542	2	6/10/86
-120.406	36.6542	2	5/29/86
-120.405	36.6475	3	4/1/86
-120.405	36.6467	3	5/10/84
-120.397	36.6394	1	8/7/84
-120.386	36.6331	5	5/10/84
-120.378	37.2633	2	7/25/95
-120.376	36.7703	1	8/8/84
-120.376	36.7703	1	8/8/84
-120.376	36.7703	1	1/24/84
-120.376	36.7964	1	5/13/85
-120.372	36.7556	2	8/28/90
-120.372	36.7556	4	8/26/90
-120.372	36.7556	1	8/23/90
-120.370	36.5436	2	5/16/84
-120.369	37.2864	5	6/26/85
-120.369	37.2864	4	6/29/84
-120.369	37.2864	5	7/26/83
-120.369	36.5750	4	5/16/84
-120.369	36.6464	3	8/7/84
-120.369	36.5744	12	5/14/84
-120.361	36.5733	3	5/16/84
-120.360	36.7050	1	8/8/84
-120.360	36.7050	1	1/24/84
-120.360	36.7306	1	8/8/84
-120.360	36.7306	1	1/24/84
-120.360	36.6464	4	8/6/84
-120.360	36.7194	1	8/8/84
-120.360	36.7194	1	1/24/84
-120.359	36.7200	1	5/8/84
-120.352	36.6903	2	8/8/84
-120.352	36.6903	1	1/24/84
-120.351	36.6464	2	8/7/84
-120.351	36.6319	4	5/20/84
-120.351	36.6903	1	5/8/84
-120.351	36.5453	1	5/15/84
-120.343	36.6758	1	8/8/84
-120.343	36.6758	2	1/24/84
-120.342	36.6464	3	8/6/84
-120.334	36.6611	4	8/8/84
-120.333	36.6464	3	8/7/84
-120.326	36.6467	1	8/8/84
-120.326	36.6467	1	1/24/84
-120.326	36.6464	29	8/6/84
-120.323	37.2894	4	6/25/85
-120.316	36.7564	1	3/26/85
-120.311	36.1572	1	8/13/86
-120.284	36.5742	1	5/15/84
-120.279	36.5450	2	5/16/84
-120.278	36.6019	3	5/15/84
-120.276	36.1558	2	8/13/86
-120.247	36.4572	2	5/18/84
-120.246	36.6519	13	5/14/85
-120.246	36.6519	14	3/25/85
-120.224	36.5019	2	5/17/84
-120.223	36.7322	5	7/6/87
-120.223	36.7322	7	7/6/87
-120.211	36.3997	1	5/15/84
-120.210	36.4583	2	5/18/84
-120.206	36.5311	1	5/17/84
-120.193	36.3997	2	5/16/84
-120.187	36.4878	2	5/17/84
-120.178	36.4297	1	5/16/84
-120.156	36.4292	2	5/16/84
-120.156	36.4586	2	5/17/84
-120.128	36.4417	1	5/16/85
-120.112	36.3358	1	3/27/85
-120.112	36.3386	1	5/15/85
-120.112	36.3386	1	3/27/85
-120.104	36.4156	4	5/17/84
-120.103	36.4453	1	5/16/84
-120.098	36.3856	1	5/19/84
-120.096	35.9900	7	8/12/86
-120.093	36.1017	1	8/8/86
-120.092	36.1164	1	8/8/86
-120.092	36.1164	1	7/1/85
-120.085	36.4294	2	5/17/84
-120.085	36.4403	2	5/19/84
-120.073	36.8225	2	6/17/87
-120.073	36.8225	30	6/17/87
-120.065	36.4158	1	5/17/84
-120.058	35.9061	7	8/13/86
-120.029	36.1478	1	5/15/85
-120.029	36.3139	1	7/19/79
-120.029	36.3867	2	5/17/84
-120.024	37.0400	1	6/5/87
-120.007	36.0947	1	5/20/84
-120.006	36.5458	5	7/8/87
-119.998	36.8500	1	6/17/87
-119.994	36.3581	2	5/17/84
-119.994	36.3286	2	5/17/84
-119.994	36.3433	82	5/17/84
-119.984	36.0803	1	5/20/84
-119.984	36.0944	2	5/19/84
-119.983	36.1378	1	5/17/84
-119.980	36.4853	1	5/16/85
-119.978	36.3306	1	5/20/84
-119.976	36.4008	1	5/16/85
-119.960	36.0072	15	8/9/86
-119.957	36.0508	1	5/18/84
-119.948	35.9928	10	8/9/86
-119.948	36.0944	1	5/18/84
-119.947	36.3233	1	7/2/85
-119.940	36.2267	2	5/20/84
-119.930	36.0800	2	5/18/84
-119.926	36.4856	9	8/3/87
-119.923	36.1381	1	5/18/84
-119.921	36.2556	2	5/18/84
-119.915	36.2661	1	8/19/86
-119.905	36.1381	1	5/18/84
-119.905	36.1522	1	5/18/84
-119.904	36.2550	1	5/18/84
-119.904	36.2261	1	5/19/84
-119.896	36.4475	30	7/18/79
-119.891	36.9789	1	6/16/87
-119.886	36.1892	3	5/18/84
-119.873	36.3881	21	5/15/85
-119.868	36.2769	3	5/19/84

-119.851	36.3656	1	12/3/84
-119.851	36.3656	1	7/23/84
-119.850	36.2697	8	12/5/84
-119.844	36.1897	10	12/6/84
-119.844	36.1897	15	7/26/84
-119.833	36.2411	18	12/5/84
-119.833	36.2411	32	7/26/84
-119.827	36.2039	17	12/6/84
-119.827	36.2039	20	7/26/84
-119.824	36.3303	1	7/23/84
-119.819	36.8444	3	6/18/87
-119.815	36.3133	3	12/4/84
-119.815	36.3133	10	7/24/84
-119.814	36.1606	1	8/13/86
-119.810	36.3117	11	12/4/84
-119.810	36.3117	13	7/27/84
-119.798	36.2400	2	8/13/86
-119.798	36.1831	15	12/5/84
-119.798	36.1831	11	7/26/84
-119.789	36.5089	3	7/21/87
-119.779	36.2400	11	7/25/84
-119.779	36.2111	1	12/6/84
-119.779	36.2111	1	7/25/84
-119.772	36.4967	13	7/21/87
-119.763	36.5625	1	7/17/79
-119.753	36.4269	6	6/28/95
-119.753	36.4269	1	6/28/95
-119.743	36.2106	10	7/25/84
-119.707	36.3189	5	8/19/86
-119.706	36.3147	140	8/19/86
-119.703	36.2097	1	8/12/86
-119.666	36.5831	2	7/17/79
-119.664	36.4467	3	7/22/87
-119.658	36.4456	1	7/22/87
-119.648	36.7164	1	9/1/94
-119.648	36.7164	1	8/31/94
-119.648	36.7164	2	8/31/94
-119.646	37.2811	1	10/27/93
-119.637	37.3639	1	10/27/93
-119.634	36.7161	1	8/4/94
-119.624	36.7153	1	8/3/94
-119.624	36.7153	2	8/3/94
-119.624	36.7153	1	6/16/94
-119.609	36.3831	8	7/23/87
-119.602	36.7211	2	8/4/94
-119.596	36.7272	2	8/30/94
-119.596	36.7272	3	8/30/94
-119.596	36.7272	2	6/17/94
-119.574	36.7533	2	8/5/87
-119.538	36.7128	1	6/24/87
-119.525	35.7175	33	8/10/86
-119.525	35.7175	33	8/10/86
-119.486	36.4556	2	7/23/87
-119.486	36.4556	2	7/23/87
-119.467	36.2281	1	6/27/95
-119.467	36.2281	2	6/27/95
-119.467	36.2281	2	6/27/95
-119.467	36.2281	1	6/27/95
-119.435	36.4336	4	7/23/87
-119.435	36.4336	4	7/23/87
-119.428	35.7978	64	8/9/86
-119.428	35.7978	64	8/9/86
-119.418	36.3464	8	7/29/87
-119.418	36.3464	8	7/29/87
-119.408	36.0508	4	8/26/86
-119.408	36.0508	4	8/26/86
-119.403	36.2906	1	5/23/95
-119.403	36.2906	1	5/23/95
-119.395	36.2881	1	6/26/95
-119.395	36.2881	1	6/26/95
-119.395	36.2881	1	6/26/95
-119.395	36.2881	1	6/26/95
-119.383	35.8050	46	8/12/86
-119.383	35.8050	46	8/12/86
-119.336	36.2242	2	7/28/87
-119.336	36.2242	2	7/28/87
-119.308	36.0614	7	8/27/86
-119.308	36.0614	7	8/27/86
-119.291	36.2267	1	7/28/87
-119.291	36.2267	1	7/28/87
-119.276	36.4400	5	7/29/87
-119.276	36.4400	5	7/29/87
-119.274	36.6250	1	7/10/87
-119.274	36.6250	1	7/10/87
-119.197	35.9422	3	8/6/86
-119.197	35.9422	3	8/6/86
-119.197	36.0214	1	8/13/86
-119.197	36.0214	1	8/13/86
-119.152	36.2139	5	7/30/87
-119.152	36.2139	5	7/30/87
-119.146	36.0589	1	8/27/86
-119.146	36.0589	1	8/27/86
-119.095	36.4006	3	8/4/87
-119.095	36.4006	2	8/4/87
-119.095	36.4006	3	8/4/87
-119.095	36.4006	2	8/4/87
-119.071	35.8978	2	8/7/86
-119.071	35.8978	2	8/7/86
-119.048	35.8942	8	8/8/86
-119.048	35.8942	8	8/8/86
-119.046	36.0964	1	8/27/86
-119.046	36.0964	1	8/27/86
-119.043	35.9033	18	8/6/86
-119.043	35.9033	18	8/6/86
-119.043	35.9033	18	8/6/86
-119.043	35.9033	18	8/6/86

Boron Dissolved (µg/L as B)

Longitude	Latitude	Result	Date
-121.548	37.8017	10000	6/6/79
-121.548	37.8017	10000	6/6/79
-121.499	37.7589	2500	5/5/84
-121.499	37.7589	2500	5/5/84
-121.468	38.2256	500	5/15/78
-121.468	38.2256	500	5/15/78
-121.435	37.7961	200	6/6/79
-121.435	37.7961	200	6/6/79
-121.432	37.7792	2000	5/5/84
-121.432	37.7792	2000	5/5/84
-121.400	37.7244	1400	5/23/79
-121.400	37.7244	1400	5/23/79
-121.398	38.2083	200	5/17/78
-121.398	38.2083	200	5/17/78
-121.378	37.7161	1900	5/23/79
-121.378	37.7161	1900	5/23/79
-121.366	37.8553	400	6/6/79
-121.366	37.8553	400	6/6/79
-121.361	37.6864	900	6/12/79
-121.361	37.6864	900	6/12/79
-121.361	37.6864	1000	7/21/70
-121.361	37.6864	1000	7/21/70
-121.361	37.6458	500	6/13/79
-121.361	37.6458	500	6/13/79
-121.360	37.6933	1600	3/11/85
-121.360	37.6933	1600	3/11/85
-121.360	37.7325	800	5/23/79
-121.360	37.7325	800	5/23/79
-121.358	38.0314	20	6/14/78
-121.358	38.0314	20	6/14/78
-121.358	38.0314	0	7/27/70
-121.358	38.0314	0	7/27/70
-121.352	38.1547	30	5/18/78
-121.352	38.1547	30	5/18/78
-121.342	38.0739	20	6/5/78
-121.342	38.0739	20	6/5/78
-121.341	38.0319	20	6/14/78
-121.341	38.0319	20	6/14/78
-121.339	38.0869	20	5/31/78
-121.339	38.0869	20	5/31/78
-121.339	38.1181	20	6/1/78
-121.339	38.1181	20	6/1/78
-121.334	37.9439	700	5/2/79
-121.334	37.9439	700	5/2/79
-121.333	37.6011	500	6/14/79
-121.333	37.6011	500	6/14/79
-121.327	37.6711	900	6/13/79
-121.327	37.6711	900	6/13/79
-121.325	38.0250	0	5/13/71
-121.325	38.0250	0	5/13/71
-121.322	37.5992	430	3/13/85
-121.311	37.7139	2800	5/14/84
-121.311	37.7139	2800	5/14/84
-121.308	38.0281	100	6/29/78
-121.308	38.0281	100	6/29/78
-121.305	38.1272	20	5/31/78
-121.305	38.1272	20	5/31/78
-121.297	38.1458	20	5/18/78
-121.297	38.1458	20	5/18/78
-121.285	37.8400	200	5/13/71
-121.285	37.8400	200	5/13/71
-121.275	38.2439	20	5/15/78
-121.275	38.2439	20	5/15/78
-121.261	37.9392	20	5/2/79
-121.261	37.9392	20	5/2/79
-121.261	37.9392	0	7/22/70
-121.261	37.9392	0	7/22/70
-121.258	38.0942	20	6/6/78
-121.258	38.0942	20	6/6/78
-121.248	38.0317	20	6/14/78
-121.248	38.0317	20	6/14/78
-121.248	38.0317	0	7/27/70
-121.248	38.0317	0	7/27/70
-121.246	37.9214	20	5/8/79
-121.246	37.9214	20	5/8/79
-121.245	38.0372	20	6/14/78
-121.245	38.0372	20	6/14/78
-121.243	38.1339	20	6/6/78
-121.243	38.1339	20	6/6/78
-121.237	37.7697	100	6/10/75
-121.237	37.7697	100	6/10/75
-121.236	38.0094	20	6/20/78
-121.236	38.0094	20	6/20/78
-121.232	37.6281	3600	5/5/84
-121.215	37.9319	500	6/29/78
-121.215	37.9319	500	6/29/78
-121.215	37.6150	1100	5/6/84
-121.213	37.9800	40	6/22/78
-121.213	37.9800	40	6/22/78
-121.209	37.9642	100	6/29/78
-121.209	37.9642	100	6/29/78
-121.207	37.5839	1200	5/6/84
-121.207	38.1878	20	5/22/78

-121.207	38.1878	20	5/22/78
-121.200	37.5494	900	3/12/85
-121.194	37.7361	100	5/17/79
-121.194	37.7361	100	5/17/79
-121.186	38.0317	20	6/14/78
-121.186	38.0317	20	6/14/78
-121.184	37.4786	1200	5/16/85
-121.180	37.9728	20	6/21/78
-121.180	37.9728	20	6/21/78
-121.174	37.7989	100	5/9/79
-121.174	37.7989	100	5/9/79
-121.174	37.8647	100	5/8/79
-121.174	37.8647	100	5/8/79
-121.165	38.2344	20	5/18/78
-121.165	38.2344	20	5/18/78
-121.165	37.9061	20	5/3/79
-121.165	37.9061	20	5/3/79
-121.165	37.9061	100	7/24/70
-121.165	37.9061	100	7/24/70
-121.163	37.9914	20	6/21/78
-121.163	37.9914	20	6/21/78
-121.163	37.9914	0	7/28/70
-121.163	37.9914	0	7/28/70
-121.156	37.5433	580	5/1/85
-121.155	37.9453	20	5/8/79
-121.155	37.9453	20	5/8/79
-121.150	38.0361	20	6/20/78
-121.150	38.0361	20	6/20/78
-121.150	38.0361	100	7/23/71
-121.150	38.0361	100	7/23/71
-121.144	37.5375	590	3/13/85
-121.143	37.7400	100	5/17/79
-121.143	37.7400	100	5/17/79
-121.143	37.7400	100	7/20/70
-121.143	37.7400	100	7/20/70
-121.142	37.4361	860	5/16/85
-121.133	37.5967	480	7/2/85
-121.111	38.1667	20	5/24/78
-121.111	38.1667	20	5/24/78
-121.109	37.4561	670	4/30/85
-121.106	37.7456	100	5/17/79
-121.106	37.7456	100	5/17/79
-121.106	37.7456	20	6/19/74
-121.106	37.7456	20	6/19/74
-121.106	37.7456	200	7/21/72
-121.106	37.7456	200	7/21/72
-121.101	38.1225	20	6/7/78
-121.101	38.1225	20	6/7/78
-121.093	37.4850	1800	5/5/84
-121.082	37.4550	1200	5/6/84
-121.079	37.4936	2400	11/17/88
-121.079	37.4653	540	5/4/84
-121.079	37.4939	2500	11/17/88
-121.079	37.4908	2200	4/30/85
-121.076	37.2753	430	5/7/84
-121.075	37.2897	470	5/13/85
-121.058	37.4303	600	5/5/84
-121.053	37.1881	870	5/6/84
-121.053	37.8781	100	5/9/79
-121.053	37.8781	100	5/9/79
-121.052	37.8481	20	5/9/79
-121.052	37.8481	20	5/9/79
-121.052	37.8481	0	7/23/70
-121.052	37.8481	0	7/23/70
-121.051	37.3917	230	5/7/84
-121.049	37.1881	290	5/6/84
-121.048	37.2742	560	5/7/84
-121.048	38.0267	20	6/22/78
-121.048	38.0267	20	6/22/78
-121.048	38.0267	0	7/28/70
-121.048	38.0267	0	7/28/70
-121.047	37.6044	60	5/1/85
-121.039	38.1533	20	5/25/78
-121.039	38.1533	20	5/25/78
-121.021	37.3758	1400	5/7/84
-121.017	37.3156	430	8/8/79
-121.016	38.0344	20	6/22/78
-121.016	38.0344	20	6/22/78
-121.013	37.2322	580	5/7/84
-121.012	37.4311	340	11/16/88
-121.008	37.2275	300	5/5/84
-121.006	37.2533	410	9/12/85
-120.999	37.2425	470	3/27/85
-120.999	37.6511	220	8/6/79
-120.996	37.2533	380	9/12/85
-120.995	37.6375	390	9/8/71
-120.995	37.6375	700	6/8/70
-120.995	37.6375	200	3/12/70
-120.992	37.9394	20	6/27/78
-120.992	37.9394	20	6/27/78
-120.992	37.4386	290	5/15/85
-120.991	37.1883	2000	5/8/84
-120.991	37.3317	1900	5/7/84
-120.988	37.7989	20	5/15/79
-120.988	37.7989	20	5/15/79
-120.988	37.7989	0	8/18/72
-120.988	37.7989	0	8/18/72
-120.984	37.7981	20	5/16/79
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-120.984	37.3558	1400	5/5/84
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-120.980	37.4342	540	5/21/85
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-120.960	37.7547	20	5/15/79
-120.960	37.7547	20	5/15/79
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-120.956	37.1453	1400	3/28/85
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-120.947	37.9147	100	7/24/70
-120.947	37.9147	100	7/24/70
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-120.944	37.8617	0	7/23/70
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-120.944	38.0458	20	6/27/78
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-120.925	37.0817	920	5/8/84
-120.921	37.4025	630	8/8/79
-120.914	37.0922	1700	5/6/84
-120.906	37.3539	50	7/27/83
-120.896	37.3092	2900	5/13/85
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-120.854	37.0461	670	8/8/79
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-120.853	37.0522	710	9/11/85
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-120.837	37.3344	120	5/14/85
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-120.707	36.8361	3800	8/13/79
-120.687	37.1858	40	4/10/85
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-120.573	36.9733	500	8/14/79
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-120.413	36.6517	15000	6/11/87
-120.413	36.6517	27000	6/11/87
-120.413	36.6517	15000	6/11/87
-120.413	36.6517	17000	6/10/87
-120.413	36.6517	39000	6/10/87
-120.413	36.6517	28000	6/10/87
-120.413	36.6517	17000	6/9/87
-120.413	36.6517	24000	6/9/87
-120.413	36.6517	16000	6/9/87
-120.413	36.6517	25000	2/4/86
-120.413	36.6517	8500	2/4/86
-120.413	36.6517	10000	2/4/86
-120.413	36.6517	8700	2/3/86
-120.413	36.6517	29000	1/31/86
-120.413	36.6542	12000	8/7/84
-120.410	36.6517	36000	7/30/86
-120.410	36.6517	24000	7/30/86
-120.410	36.6517	11000	7/30/86
-120.410	36.6517	30000	7/17/86
-120.410	36.6517	5700	7/17/86
-120.410	36.6517	37000	7/17/86
-120.410	36.6517	18000	2/4/86
-120.410	36.6517	15000	2/4/86
-120.407	36.6506	7300	9/1/88
-120.407	36.6506	29000	9/1/88
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-120.407	36.6506	27000	8/31/88
-120.407	36.6506	9700	8/31/88
-120.407	36.6506	14000	8/30/88
-120.407	36.6506	21000	8/30/88
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-120.407	36.6506	22000	8/30/88
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-120.407	36.6506	23000	8/30/88
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-120.407	36.6506	40000	8/13/86
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-120.407	36.6506	19000	8/13/86
-120.407	36.6506	28000	8/13/86
-120.407	36.6506	20000	8/12/86
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-120.407	36.6506	18000	8/12/86
-120.407	36.6506	21000	8/11/86
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-120.407	36.6506	35000	7/30/86
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-120.407	36.6506	24000	7/28/86
-120.407	36.6506	16000	7/28/86
-120.407	36.6506	26000	7/28/86
-120.407	36.6506	12000	7/28/86
-120.407	36.6506	18000	7/28/86
-120.407	36.6506	11000	7/17/86
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-120.407	36.6506	13000	5/22/86
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-120.407	36.6506	22000	3/6/86
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-120.407	36.6506	27000	2/26/86
-120.407	36.6506	21000	2/26/86
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-120.407	36.6506	27000	2/6/86
-120.407	36.6506	21000	2/6/86

-120.407	36.6506	11000	2/6/86
-120.407	36.6506	23000	2/6/86
-120.407	36.6506	31000	2/6/86
-120.407	36.6506	29000	2/5/86
-120.407	36.6506	30000	2/5/86
-120.407	36.6506	35000	2/5/86
-120.407	36.6506	16000	2/5/86
-120.407	36.6506	37000	2/5/86
-120.407	36.6506	10000	2/4/86
-120.406	36.6542	22000	9/20/88
-120.406	36.6542	8700	5/23/88
-120.406	36.6542	9100	4/27/88
-120.406	36.6542	13000	3/25/88
-120.406	36.6542	13000	2/25/88
-120.406	36.6542	17000	2/3/88
-120.406	36.6542	17000	1/24/88
-120.406	36.6542	21000	11/24/87
-120.406	36.6542	20000	11/13/87
-120.406	36.6542	19000	11/5/87
-120.406	36.6542	19000	11/4/87
-120.406	36.6542	17000	10/22/87
-120.406	36.6542	16000	10/21/87
-120.406	36.6542	17000	10/20/87
-120.406	36.6542	11000	10/15/87
-120.406	36.6542	11000	7/31/87
-120.406	36.6542	27000	6/30/87
-120.406	36.6542	14000	5/7/87
-120.406	36.6542	11000	4/16/87
-120.406	36.6542	9700	3/27/87
-120.406	36.6542	21000	9/26/86
-120.406	36.6542	9900	6/10/86
-120.406	36.6542	9500	5/29/86
-120.405	36.6475	5900	4/1/86
-120.405	36.6467	14000	5/10/84
-120.397	36.6394	7900	8/7/84
-120.386	36.6331	37000	5/10/84
-120.376	36.7703	11000	8/8/84
-120.376	36.7703	14000	8/8/84
-120.376	36.7703	9500	1/24/84
-120.376	36.7964	110	5/13/85
-120.372	36.7556	850	8/28/90
-120.372	36.7556	1200	8/26/90
-120.372	36.7556	750	8/23/90
-120.370	36.5436	5800	5/16/84
-120.369	37.2864	30	7/26/83
-120.369	36.5750	5700	5/16/84
-120.369	36.6464	69000	8/7/84
-120.369	36.5744	13000	5/14/84
-120.361	36.5733	5500	5/16/84
-120.360	36.7050	12000	8/8/84
-120.360	36.7050	8900	1/24/84
-120.360	36.7306	8600	8/8/84
-120.360	36.7306	7900	1/24/84
-120.360	36.6464	66000	8/6/84
-120.360	36.7194	9000	8/8/84
-120.360	36.7194	19000	1/24/84
-120.359	36.7200	8800	5/8/84
-120.352	36.6903	29000	8/8/84
-120.352	36.6903	14000	1/24/84
-120.351	36.6464	41000	8/7/84
-120.351	36.6319	100000	5/20/84
-120.351	36.6903	10000	5/8/84
-120.351	36.5453	720	5/15/84
-120.346	36.4575	2000	8/14/79
-120.343	36.6758	11000	8/8/84
-120.343	36.6758	14000	1/24/84
-120.342	36.6464	62000	8/6/84
-120.334	36.6611	16000	8/8/84
-120.333	36.6464	44000	8/7/84
-120.327	37.1322	20	8/10/79
-120.326	36.6467	15000	8/8/84
-120.326	36.6467	21000	1/24/84
-120.326	36.6464	1900	8/6/84
-120.316	36.7564	100	3/26/85
-120.311	36.1572	1300	8/13/86
-120.284	36.5742	14000	5/15/84
-120.279	36.5450	470	5/16/84
-120.278	36.6019	6900	5/15/84
-120.276	36.1558	1400	8/13/86
-120.264	37.1708	10	7/25/70
-120.247	36.4572	950	5/18/84
-120.246	36.6519	1100	5/14/85
-120.246	36.6519	1000	3/25/85
-120.244	37.2361	20	8/13/79
-120.224	36.5019	3900	5/17/84
-120.223	36.7322	320	7/6/87
-120.223	36.7322	330	7/6/87
-120.211	36.3997	1300	5/15/84
-120.210	36.4583	12000	5/18/84
-120.206	36.5311	29000	5/17/84
-120.193	36.3997	29000	5/16/84
-120.187	36.4878	2300	5/17/84
-120.178	36.4297	640	5/16/84
-120.156	36.4292	930	5/16/84
-120.156	36.4586	1500	5/17/84
-120.128	36.4417	930	5/16/85
-120.112	36.3358	880	3/27/85
-120.112	36.3386	6200	5/15/85
-120.112	36.3386	6500	3/27/85
-120.104	36.4156	2400	5/17/84
-120.103	36.4453	25000	5/16/84
-120.098	36.3856	6000	5/19/84
-120.096	35.9900	660	8/12/86
-120.093	36.1017	450	8/8/86
-120.092	36.1164	430	8/8/86
-120.092	36.1164	410	7/1/85
-120.085	36.4294	1100	5/17/84
-120.085	36.4403	25000	5/19/84
-120.073	36.8225	26	6/17/87
-120.073	36.8225	26	6/17/87
-120.065	36.4158	3100	5/17/84
-120.058	35.9061	1400	8/13/86
-120.029	36.1478	520	5/15/85
-120.029	36.3139	790	7/19/79
-120.029	36.3867	180	5/17/84
-120.024	37.0400	30	6/5/87
-120.007	36.0947	1600	5/20/84
-120.006	36.5458	20	7/8/87
-119.998	36.8500	40	6/17/87
-119.994	36.3581	2300	5/17/84
-119.994	36.3286	660	5/17/84
-119.994	36.3433	1400	5/17/84
-119.984	36.0803	2900	5/20/84
-119.984	36.0944	640	5/19/84
-119.983	36.1378	2300	5/17/84
-119.980	36.4853	270	5/16/85
-119.978	36.3306	8100	5/20/84
-119.976	36.4008	1200	5/16/85
-119.960	36.0072	580	8/9/86
-119.957	36.0508	14000	5/18/84
-119.948	35.9928	800	8/9/86
-119.948	36.0944	4900	5/18/84
-119.947	36.3233	1700	7/2/85
-119.940	36.2267	26000	5/20/84
-119.930	36.0800	34000	5/18/84
-119.926	36.4856	200	8/3/87
-119.923	36.1381	6600	5/18/84
-119.921	36.2556	2800	5/18/84
-119.915	36.2661	2100	8/19/86
-119.905	36.1381	19000	5/18/84
-119.905	36.1522	40000	5/18/84
-119.904	36.2550	7400	5/18/84
-119.904	36.2261	4400	5/19/84
-119.896	36.4475	1300	7/18/79
-119.891	36.9789	20	6/16/87
-119.886	36.1892	7100	5/18/84
-119.873	36.3881	360	5/15/85
-119.868	36.2769	16000	5/19/84
-119.851	36.3656	300	12/3/84
-119.851	36.3656	410	7/23/84
-119.850	36.2697	1900	12/5/84
-119.844	36.1897	1300	12/6/84
-119.844	36.1897	1400	7/26/84
-119.835	36.5333	180	7/17/79
-119.833	36.2411	8200	12/5/84
-119.833	36.2411	5800	7/26/84
-119.827	36.2039	15000	12/6/84
-119.827	36.2039	13000	7/26/84
-119.824	36.3303	110	7/23/84
-119.819	36.8444	30	6/18/87
-119.815	36.3133	260	12/4/84
-119.815	36.3133	250	7/24/84
-119.814	36.1606	260	8/13/86
-119.814	36.1606	270	8/17/79
-119.810	36.3117	920	12/4/84
-119.810	36.3117	840	7/27/84
-119.798	36.2400	960	8/13/86
-119.798	36.5297	20	7/17/79
-119.798	36.1831	2800	12/5/84
-119.798	36.1831	3200	7/26/84
-119.794	36.8861	60	8/15/79
-119.789	36.5089	30	7/21/87
-119.779	36.2400	190	7/25/84
-119.779	36.2111	1200	12/6/84
-119.779	36.2111	1500	7/25/84
-119.772	36.4967	50	7/21/87
-119.763	36.5625	40	7/17/79
-119.743	36.2106	1400	7/25/84
-119.707	36.3189	660	8/19/86
-119.706	36.3147	240	8/19/86
-119.703	36.2097	1500	8/12/86
-119.697	36.8011	20	6/24/87
-119.666	36.5831	40	7/17/79
-119.664	36.4467	30	7/22/87
-119.658	36.4456	20	7/22/87
-119.646	37.2811	30	10/27/93
-119.637	37.3639	1500	10/27/93
-119.609	36.3831	20	7/23/87
-119.574	36.7533	20	8/5/87
-119.574	36.7181	30	7/16/79
-119.538	36.7128	10	6/24/87
-119.525	35.7175	70	8/10/86
-119.525	35.7175	70	8/10/86
-119.491	36.1058	50	8/23/79
-119.491	36.1058	50	8/23/79
-119.486	36.4556	40	7/23/87
-119.486	36.4556	40	7/23/87
-119.435	36.4336	40	7/23/87
-119.435	36.4336	40	7/23/87
-119.428	35.7978	100	8/9/86
-119.428	35.7978	100	8/9/86
-119.418	36.3464	20	7/29/87
-119.418	36.3464	20	7/29/87
-119.408	36.0508	90	8/26/86

-119.408	36.0508	90	8/26/86
-119.385	35.8578	210	8/22/79
-119.385	35.8578	210	8/22/79
-119.383	35.8050	90	8/12/86
-119.383	35.8050	90	8/12/86
-119.339	36.2078	20	8/23/79
-119.339	36.2078	20	8/23/79
-119.336	36.2242	30	7/28/87
-119.336	36.2242	30	7/28/87
-119.334	36.2147	20	8/23/79
-119.334	36.2147	20	8/23/79
-119.308	36.0614	70	8/27/86
-119.308	36.0614	70	8/27/86
-119.291	36.2267	20	7/28/87
-119.291	36.2267	20	7/28/87
-119.276	36.4400	133	7/29/87
-119.276	36.4400	133	7/29/87
-119.274	36.6250	20	7/10/87
-119.274	36.6250	20	7/10/87
-119.215	35.9144	50	8/22/79
-119.215	35.9144	50	8/22/79
-119.197	35.9422	40	8/6/86
-119.197	35.9422	40	8/6/86
-119.197	36.0214	70	8/13/86
-119.197	36.0214	70	8/13/86
-119.152	36.2139	120	7/30/87
-119.152	36.2139	120	7/30/87
-119.146	36.0589	140	8/27/86
-119.146	36.0589	140	8/27/86
-119.095	36.4006	20	8/4/87
-119.095	36.4006	10	8/4/87
-119.095	36.4006	20	8/4/87
-119.095	36.4006	10	8/4/87
-119.071	35.8978	50	8/7/86
-119.071	35.8978	50	8/7/86
-119.048	35.8942	570	8/8/86
-119.048	35.8942	570	8/8/86
-119.046	36.0964	130	8/27/86
-119.046	36.0964	130	8/27/86
-119.046	36.0964	80	8/22/79
-119.046	36.0964	80	8/22/79
-119.043	35.9033	70	8/6/86
-119.043	35.9033	70	8/6/86
-119.043	35.9033	70	8/6/86
-119.043	35.9033	70	8/6/86

Lead Dissolved (µg/L as Pb)

Longitude	Latitude	Result	Date
-121.499	37.7589	1	5/5/84
-121.499	37.7589	1	5/5/84
-121.432	37.7792	3	5/5/84
-121.432	37.7792	3	5/5/84
-121.360	37.6933	1	3/11/85
-121.360	37.6933	1	3/11/85
-121.322	37.5992	1	3/13/85
-121.311	37.7139	3	5/14/84
-121.311	37.7139	3	5/14/84
-121.261	37.9392	0	7/22/70
-121.261	37.9392	0	7/22/70
-121.232	37.6281	1	5/5/84
-121.215	37.9319	4	6/29/78
-121.215	37.9319	4	6/29/78
-121.215	37.6150	1	5/6/84
-121.207	37.5839	1	5/6/84
-121.200	37.5494	1	3/12/85
-121.184	37.4786	5	5/16/85
-121.156	37.5433	1	5/1/85
-121.144	37.5375	1	3/13/85
-121.142	37.4361	3	5/16/85
-121.133	37.5967	4	7/2/85
-121.109	37.4561	1	4/30/85
-121.106	37.7456	0	6/19/74
-121.106	37.7456	0	6/19/74
-121.093	37.4850	1	5/5/84
-121.082	37.4550	1	5/6/84
-121.079	37.4936	5	11/17/88
-121.079	37.4653	1	5/4/84
-121.079	37.4939	5	11/17/88
-121.079	37.4908	1	4/30/85
-121.076	37.2753	1	5/7/84
-121.075	37.2897	1	5/13/85
-121.058	37.4303	1	5/5/84
-121.053	37.1881	1	5/6/84
-121.051	37.3917	3	5/7/84
-121.049	37.1881	1	5/6/84
-121.048	37.2742	1	5/7/84
-121.047	37.6044	1	5/1/85
-121.021	37.3758	1	5/7/84
-121.013	37.2322	4	5/7/84
-121.012	37.4311	5	11/16/88
-121.008	37.2275	1	5/5/84
-121.006	37.2533	2	9/12/85
-120.999	37.2425	2	3/27/85
-120.997	37.5206	1	7/18/95
-120.996	37.2533	1	9/12/85
-120.992	37.4386	4	5/15/85
-120.991	37.1883	2	5/8/84
-120.991	37.3317	5	5/7/84
-120.984	37.3558	1	5/5/84
-120.981	37.2917	1	5/5/84
-120.980	37.4342	1	5/21/85
-120.978	37.2897	1	5/7/84
-120.975	37.3508	5	11/15/88
-120.959	37.0997	1	5/7/84
-120.956	37.1453	4	3/28/85
-120.956	37.1453	1	3/28/85
-120.949	37.2842	1	5/21/84
-120.938	37.0644	1	5/6/84
-120.925	37.0817	5	5/8/84
-120.914	37.0922	1	5/6/84
-120.906	37.3539	1	6/27/85
-120.896	37.3092	4	5/13/85
-120.895	37.1139	2	4/9/85
-120.895	37.2456	1	8/9/84
-120.853	37.0522	3	9/11/85
-120.853	37.0522	3	9/11/85
-120.843	37.1000	2	4/9/85
-120.839	37.0561	6	4/11/85
-120.839	37.0561	5	4/11/85
-120.837	37.3344	1	5/14/85
-120.836	37.0125	1	5/6/84
-120.836	36.9956	2	5/5/84
-120.836	37.4286	1	6/27/85
-120.836	36.9986	1	5/9/84
-120.821	37.0997	1	8/9/84
-120.820	37.1000	1	8/9/84
-120.818	36.9542	1	5/14/84
-120.818	36.9267	1	5/15/84
-120.813	37.1600	4	4/10/85
-120.800	36.9314	1	5/14/84
-120.792	37.5442	9	7/28/94
-120.776	36.9228	5	5/15/84
-120.760	37.0786	3	5/10/84
-120.753	36.8939	1	5/21/84
-120.753	36.8939	6	5/10/84
-120.746	36.9022	2	5/10/84
-120.736	36.9044	1	5/10/84
-120.687	37.1858	2	4/10/85
-120.677	37.5889	5	5/20/87
-120.670	37.0975	5	5/10/84
-120.657	36.8067	1	5/9/84
-120.657	36.8344	4	4/11/85
-120.657	36.8344	4	4/11/85
-120.657	36.8344	4	4/11/85
-120.657	36.8344	2	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	5	4/10/85
-120.657	36.8344	5	4/10/85
-120.657	36.8344	3	4/10/85
-120.657	36.8344	1	4/10/85
-120.657	36.8344	6	4/10/85
-120.657	36.8344	4	4/10/85
-120.655	36.8358	1	5/16/84
-120.653	36.8797	2	5/21/84
-120.653	36.9961	5	5/8/84
-120.643	37.3531	2	6/25/85
-120.635	37.0467	1	4/29/85
-120.626	37.3164	1	6/25/85
-120.626	36.8497	1	5/16/84
-120.616	36.8503	1	5/15/84
-120.616	36.9817	1	5/8/84
-120.616	37.0481	5	5/8/84
-120.616	37.0828	6	5/8/84
-120.615	37.0550	12	5/7/84
-120.600	36.8683	1	5/8/84
-120.600	37.2728	5	6/4/87
-120.599	36.9672	2	5/9/84
-120.595	37.3711	1	6/25/85
-120.592	36.8503	1	5/15/84
-120.588	37.3019	5	5/21/87
-120.584	36.8506	1	5/15/84
-120.584	36.9900	1	5/14/84
-120.582	37.6394	5	5/20/87
-120.580	36.8506	3	4/4/85
-120.580	36.8506	1	4/4/85
-120.580	36.8506	1	4/4/85
-120.580	36.8506	1	4/4/85
-120.580	36.8506	3	4/4/85
-120.580	36.8506	1	4/4/85
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-120.580	36.8506	4	4/3/85
-120.580	36.8506	1	4/3/85
-120.580	36.8506	2	4/3/85
-120.580	36.8506	1	4/3/85
-120.580	36.8506	2	4/3/85
-120.580	36.8506	5	4/3/85
-120.580	36.8506	1	4/2/85
-120.580	36.8506	1	4/2/85
-120.580	36.8506	4	4/2/85
-120.580	36.8506	5	4/2/85
-120.580	36.8506	3	4/2/85
-120.580	36.8506	4	4/2/85
-120.571	37.0292	1	4/30/85

-120.562	36.9958	3	5/9/84
-120.557	37.0875	7	5/14/85
-120.546	36.9261	3	5/9/84
-120.533	36.8089	4	5/9/84
-120.524	36.8383	1	8/31/89
-120.524	36.8383	1	8/31/89
-120.524	36.8383	1	3/21/85
-120.524	36.8383	3	3/21/85
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-120.524	36.8383	1	3/21/85
-120.524	36.8383	1	3/20/85
-120.524	36.8383	1	3/20/85
-120.524	36.8383	1	3/20/85
-120.524	36.8383	1	3/20/85
-120.524	36.8383	1	3/20/85
-120.524	36.8383	4	3/20/85
-120.524	36.8383	2	3/20/85
-120.524	36.8383	1	3/20/85
-120.524	36.8383	1	3/19/85
-120.524	36.8383	1	3/19/85
-120.524	36.8383	5	3/19/85
-120.524	36.8383	8	3/19/85
-120.524	36.8383	8	3/19/85
-120.524	36.8383	7	3/19/85
-120.524	36.8383	6	3/18/85
-120.524	36.8383	9	3/18/85
-120.504	36.8581	1	5/15/84
-120.490	36.8947	3	5/9/84
-120.490	36.9275	6	5/9/84
-120.486	36.9064	1	11/5/85
-120.486	36.9064	1	5/15/85
-120.478	36.6322	2	3/21/86
-120.476	36.7783	2	5/16/84
-120.474	36.8211	1	5/9/84
-120.456	36.5311	1	11/5/85
-120.456	36.5311	1	3/26/85
-120.450	37.2336	12	7/20/87
-120.442	36.6033	2	5/18/84
-120.440	36.7194	1	5/20/84
-120.435	37.2844	1	6/26/85
-120.432	36.6542	1	8/7/84
-120.427	36.8333	3	5/15/85
-120.414	36.6467	1	8/6/84
-120.413	36.6542	1	8/7/84
-120.407	36.6506	1	5/23/86
-120.407	36.6506	1	5/23/86
-120.407	36.6506	1	5/22/86
-120.407	36.6506	1	5/22/86
-120.407	36.6506	1	5/22/86
-120.407	36.6506	1	5/21/86
-120.407	36.6506	1	5/21/86
-120.407	36.6506	1	5/21/86
-120.406	36.6542	1	5/29/86
-120.405	36.6475	1	4/1/86
-120.405	36.6467	2	5/10/84
-120.397	36.6394	1	8/7/84
-120.386	36.6331	4	5/10/84
-120.378	37.2633	1	7/25/95
-120.376	36.7703	1	8/8/84
-120.376	36.7703	1	8/8/84
-120.376	36.7703	16	1/24/84
-120.376	36.7964	1	5/13/85
-120.372	36.7556	1	8/28/90
-120.372	36.7556	1	8/26/90
-120.372	36.7556	1	8/23/90
-120.370	36.5436	4	5/16/84
-120.369	37.2864	1	6/26/85
-120.369	36.5750	3	5/16/84
-120.369	36.6464	1	8/7/84
-120.369	36.5744	1	5/14/84
-120.361	36.5733	3	5/16/84
-120.360	36.7050	8	8/8/84
-120.360	36.7050	2	1/24/84
-120.360	36.7306	1	8/8/84
-120.360	36.7306	1	1/24/84
-120.360	36.6464	1	8/6/84
-120.360	36.7194	1	8/8/84
-120.360	36.7194	2	1/24/84
-120.359	36.7200	4	5/8/84
-120.352	36.6903	1	8/8/84
-120.352	36.6903	11	1/24/84
-120.351	36.6464	2	8/7/84
-120.351	36.6319	3	5/20/84
-120.351	36.6903	1	5/8/84
-120.351	36.5453	1	5/15/84
-120.343	36.6758	2	8/8/84
-120.343	36.6758	4	1/24/84
-120.342	36.6464	1	8/6/84
-120.334	36.6611	2	8/8/84
-120.333	36.6464	1	8/7/84
-120.326	36.6467	2	8/8/84
-120.326	36.6467	1	1/24/84
-120.326	36.6464	1	8/6/84
-120.323	37.2894	1	6/25/85
-120.316	36.7564	1	3/26/85
-120.311	36.1572	5	8/13/86
-120.284	36.5742	1	5/15/84
-120.279	36.5450	1	5/16/84
-120.278	36.6019	1	5/15/84
-120.276	36.1558	5	8/13/86
-120.247	36.4572	1	5/18/84
-120.246	36.6519	7	5/14/85
-120.246	36.6519	1	3/25/85
-120.224	36.5019	8	5/17/84
-120.223	36.7322	5	7/6/87
-120.223	36.7322	5	7/6/87
-120.211	36.3997	4	5/15/84
-120.210	36.4583	1	5/18/84
-120.206	36.5311	5	5/17/84
-120.193	36.3997	3	5/16/84
-120.187	36.4878	5	5/17/84
-120.178	36.4297	3	5/16/84
-120.156	36.4292	17	5/16/84
-120.156	36.4586	13	5/17/84
-120.128	36.4417	5	5/16/85
-120.112	36.3358	1	3/27/85
-120.112	36.3386	1	3/27/85
-120.104	36.4156	1	5/17/84
-120.103	36.4453	2	5/16/84
-120.098	36.3856	2	5/19/84
-120.096	35.9900	5	8/12/86
-120.093	36.1017	5	8/8/86
-120.092	36.1164	5	8/8/86
-120.092	36.1164	6	7/1/85
-120.085	36.4294	1	5/17/84
-120.085	36.4403	5	5/19/84
-120.073	36.8225	5	6/17/87
-120.073	36.8225	5	6/17/87
-120.065	36.4158	3	5/17/84
-120.058	35.9061	5	8/13/86
-120.029	36.1478	6	5/15/85
-120.029	36.3139	0	7/19/79
-120.029	36.3867	1	5/17/84
-120.024	37.0400	5	6/5/87
-120.007	36.0947	2	5/20/84
-120.006	36.5458	5	7/8/87
-119.998	36.8500	5	6/17/87
-119.994	36.3581	5	5/17/84
-119.994	36.3286	4	5/17/84
-119.994	36.3433	1	5/17/84
-119.984	36.0803	1	5/20/84
-119.984	36.0944	1	5/19/84
-119.983	36.1378	3	5/17/84
-119.980	36.4853	2	5/16/85
-119.978	36.3306	1	5/20/84
-119.976	36.4008	1	5/16/85
-119.960	36.0072	5	8/9/86
-119.957	36.0508	6	5/18/84
-119.948	35.9928	5	8/9/86
-119.948	36.0944	8	5/18/84
-119.947	36.3233	6	7/2/85
-119.940	36.2267	3	5/20/84
-119.930	36.0800	3	5/18/84
-119.926	36.4856	5	8/3/87
-119.923	36.1381	3	5/18/84
-119.921	36.2556	5	5/18/84
-119.915	36.2661	5	8/19/86
-119.905	36.1381	3	5/18/84
-119.905	36.1522	4	5/18/84
-119.904	36.2550	4	5/18/84
-119.904	36.2261	1	5/19/84
-119.896	36.4475	0	7/18/79
-119.891	36.9789	5	6/16/87
-119.886	36.1892	1	5/18/84
-119.873	36.3881	3	5/15/85
-119.868	36.2769	1	5/19/84
-119.851	36.3656	2	12/3/84
-119.851	36.3656	2	7/23/84
-119.850	36.2697	4	12/5/84
-119.844	36.1897	1	12/6/84
-119.844	36.1897	3	7/26/84
-119.833	36.2411	2	12/5/84
-119.833	36.2411	2	7/26/84
-119.827	36.2039	1	12/6/84
-119.827	36.2039	1	7/26/84
-119.824	36.3303	1	7/23/84
-119.819	36.8444	5	6/18/87
-119.815	36.3133	1	12/4/84
-119.815	36.3133	1	7/24/84
-119.814	36.1606	5	8/13/86
-119.810	36.3117	3	12/4/84
-119.810	36.3117	6	7/27/84
-119.798	36.2400	6	8/13/86
-119.798	36.1831	1	12/5/84
-119.798	36.1831	2	7/26/84
-119.789	36.5089	5	7/21/87
-119.779	36.2400	2	7/25/84
-119.779	36.2111	1	12/6/84
-119.779	36.2111	2	7/25/84
-119.772	36.4967	5	7/21/87
-119.763	36.5625	0	7/17/79
-119.753	36.4269	1	6/28/95
-119.753	36.4269	1	6/28/95
-119.743	36.2106	1	7/25/84
-119.707	36.3189	5	8/19/86
-119.706	36.3147	5	8/19/86
-119.703	36.2097	5	8/12/86
-119.666	36.5831	0	7/17/79
-119.664	36.4467	9	7/22/87

-119.658	36.4456	5	7/22/87
-119.648	36.7164	4	9/1/94
-119.648	36.7164	1	8/31/94
-119.648	36.7164	13	8/31/94
-119.646	37.2811	10	10/27/93
-119.637	37.3639	30	10/27/93
-119.634	36.7161	1	8/4/94
-119.624	36.7153	1	8/3/94
-119.624	36.7153	1	8/3/94
-119.624	36.7153	1	6/16/94
-119.609	36.3831	5	7/23/87
-119.602	36.7211	1	8/4/94
-119.596	36.7272	1	8/30/94
-119.596	36.7272	1	8/30/94
-119.596	36.7272	1	6/17/94
-119.574	36.7533	5	8/5/87
-119.538	36.7128	5	6/24/87
-119.525	35.7175	5	8/10/86
-119.525	35.7175	5	8/10/86
-119.486	36.4556	5	7/23/87
-119.486	36.4556	5	7/23/87
-119.467	36.2281	1	6/27/95
-119.467	36.2281	1	6/27/95
-119.467	36.2281	1	6/27/95
-119.467	36.2281	1	6/27/95
-119.435	36.4336	5	7/23/87
-119.435	36.4336	5	7/23/87
-119.428	35.7978	5	8/9/86
-119.428	35.7978	5	8/9/86
-119.418	36.3464	5	7/29/87
-119.418	36.3464	5	7/29/87
-119.408	36.0508	5	8/26/86
-119.408	36.0508	5	8/26/86
-119.403	36.2906	1	5/23/95
-119.403	36.2906	1	5/23/95
-119.395	36.2881	1	6/26/95
-119.395	36.2881	1	6/26/95
-119.395	36.2881	1	6/26/95
-119.395	36.2881	1	6/26/95
-119.383	35.8050	5	8/12/86
-119.383	35.8050	5	8/12/86
-119.336	36.2242	5	7/28/87
-119.336	36.2242	5	7/28/87
-119.308	36.0614	5	8/27/86
-119.308	36.0614	5	8/27/86
-119.291	36.2267	5	7/28/87
-119.291	36.2267	5	7/28/87
-119.276	36.4400	5	7/29/87
-119.276	36.4400	5	7/29/87
-119.274	36.6250	5	7/10/87
-119.274	36.6250	5	7/10/87
-119.197	35.9422	5	8/6/86
-119.197	35.9422	5	8/6/86
-119.197	36.0214	5	8/13/86
-119.197	36.0214	5	8/13/86
-119.152	36.2139	5	7/30/87
-119.152	36.2139	5	7/30/87
-119.146	36.0589	5	8/27/86
-119.146	36.0589	5	8/27/86
-119.095	36.4006	5	8/4/87
-119.095	36.4006	5	8/4/87
-119.095	36.4006	5	8/4/87
-119.095	36.4006	5	8/4/87
-119.071	35.8978	5	8/7/86
-119.071	35.8978	5	8/7/86
-119.048	35.8942	5	8/8/86
-119.048	35.8942	5	8/8/86
-119.046	36.0964	5	8/27/86
-119.046	36.0964	5	8/27/86
-119.043	35.9033	5	8/6/86
-119.043	35.9033	5	8/6/86
-119.043	35.9033	5	8/6/86
-119.043	35.9033	5	8/6/86

Solids, Sum of Constituents, Dissolved (mg/L)

Longitude	Latitude	Result	Date
-121.361	37.6864	1190	7/21/70
-121.361	37.6864	1190	7/21/70
-121.358	38.0314	276	7/27/70
-121.358	38.0314	276	7/27/70
-121.352	38.1547	127	5/18/78
-121.352	38.1547	127	5/18/78
-121.327	37.6711	524	6/13/79
-121.327	37.6711	524	6/13/79
-121.325	38.0250	374	5/13/71
-121.325	38.0250	374	5/13/71
-121.285	37.8400	324	5/13/71
-121.285	37.8400	324	5/13/71
-121.261	37.9392	200	7/22/70
-121.261	37.9392	200	7/22/70
-121.248	38.0317	165	7/27/70
-121.248	38.0317	165	7/27/70
-121.243	38.1339	161	6/6/78
-121.243	38.1339	161	6/6/78
-121.237	37.7697	370	6/10/75
-121.237	37.7697	370	6/10/75
-121.213	37.9800	372	6/22/78
-121.213	37.9800	372	6/22/78
-121.165	37.9061	158	7/24/70
-121.165	37.9061	158	7/24/70
-121.163	37.9914	151	7/28/70
-121.163	37.9914	151	7/28/70
-121.156	37.5433	827	5/1/85
-121.150	38.0361	548	7/23/71
-121.150	38.0361	548	7/23/71
-121.144	37.5375	726	3/13/85
-121.143	37.7400	198	7/20/70
-121.143	37.7400	198	7/20/70
-121.106	37.7456	288	6/19/74
-121.106	37.7456	288	6/19/74
-121.106	37.7456	252	7/21/72
-121.106	37.7456	252	7/21/72
-121.101	38.1225	156	6/7/78
-121.101	38.1225	156	6/7/78
-121.052	37.8481	263	7/23/70
-121.052	37.8481	263	7/23/70
-121.048	38.0267	200	6/22/78
-121.048	38.0267	200	6/22/78
-121.048	38.0267	140	7/28/70
-121.048	38.0267	140	7/28/70
-121.017	37.3156	555	8/8/79
-121.011	37.6117	390	12/12/78
-121.011	37.6531	305	12/11/78
-120.999	37.6511	404	8/6/79
-120.999	37.6511	410	12/12/74
-120.995	37.6375	650	12/12/74
-120.995	37.6375	1080	6/8/70
-120.993	37.6208	474	12/8/77
-120.988	37.7989	214	8/18/72
-120.988	37.7989	214	8/18/72
-120.986	37.6558	264	12/11/78
-120.983	37.5981	529	12/11/78
-120.956	37.1453	2310	3/28/85
-120.947	37.9147	184	7/24/70
-120.947	37.9147	184	7/24/70
-120.944	37.8617	192	6/24/74
-120.944	37.8617	192	6/24/74
-120.944	37.8617	173	7/23/70
-120.944	37.8617	173	7/23/70
-120.921	37.4025	1660	8/8/79
-120.854	37.0461	938	8/8/79
-120.839	37.0561	670	4/11/85
-120.813	37.1600	1180	4/10/85
-120.709	37.1022	564	8/9/79
-120.707	36.8361	1560	8/13/79
-120.576	37.3597	195	1/14/70
-120.574	37.3081	130	1/14/70
-120.573	36.9733	807	8/14/79
-120.567	36.6242	873	8/4/81
-120.500	36.9828	584	8/14/79
-120.486	36.9064	518	11/5/85
-120.456	36.5311	3670	11/5/85
-120.373	36.4944	964	8/4/81
-120.346	36.4575	1010	8/14/79
-120.327	37.1322	186	8/10/79
-120.244	37.2361	191	8/13/79
-120.091	36.1375	974	8/5/81
-120.029	36.3139	1400	7/19/79
-119.896	36.4475	362	7/18/79
-119.835	36.5333	689	7/17/79
-119.814	36.1606	420	8/17/79
-119.798	36.5297	243	7/17/79
-119.794	36.8861	115	8/15/79
-119.763	36.5625	317	7/17/79
-119.666	36.5831	85	7/17/79
-119.574	36.7181	328	7/16/79
-119.491	36.1058	204	8/23/79
-119.491	36.1058	204	8/23/79
-119.385	35.8578	225	8/22/79
-119.385	35.8578	225	8/22/79
-119.339	36.2078	123	8/23/79
-119.339	36.2078	123	8/23/79
-119.334	36.2147	97	8/23/79
-119.334	36.2147	97	8/23/79
-119.215	35.9144	188	8/22/79
-119.215	35.9144	188	8/22/79
-119.046	36.0964	356	8/22/79
-119.046	36.0964	356	8/22/79

Appendix B: Raw Soil Data

Soil Name	Thickness (in.)	Permeability	pH (rank from Table 5.2)	Hardpan (rank as described in Section 5.1)
Marvin silty clay	60	0.50	80	1.00
Zamora silty clay loam	60	0.50	80	1.00
Clear Lake clay	60	0.12	90	1.00
Altamont clay	35	0.12	100	1.00
Cortina gravelly fine sandy loam	72	10.00	45	1.00
Maywood loam	62	1.64	80	1.00
Perkins gravelly loam	60	1.64	70	1.00
Alamo-Fiddyment complex	37	0.12	75	0.00
Cometa-Fiddyment complex	60	1.02	70	1.00
Cometa-Ramona sandy loams	73	1.02	80	1.00
San Joaquin-Cometa sandy loams	60	1.02	70	0.00
Corning complex	62	1.02	50	1.00
Redding loam	66	1.02	60	0.00
Redding gravelly loam	66	1.02	60	0.00
Bruella sandy loam	61	3.00	90	0.00
Galt-urban land complex	60	0.12	75	0.00
Galt clay	60	0.12	75	0.00
Madera-Galt complex	60	0.12	75	0.00
San Joaquin silt loam	60	1.02	80	0.00
San Joaquin-Galt complex	60	1.02	75	0.00
San Joaquin-urban land complex	60	1.02	80	0.00
San Joaquin-Xerarents complex	60	1.02	80	1.00
Live oak sandy clay loam	60	3.29	75	1.00
Exeter sandy loam	60	1.10	80	1.00
Marcum clay loam	60	0.33	80	1.00
San Joaquin sandy loam	60	1.02	80	0.00
San Joaquin-Arents-Durochrepts complex	60	1.02	80	0.00
Madera fine sandy loam	60	3.02	85	0.00
Madera loam	60	1.02	85	0.00
Madera-Alamo complex	60	3.02	85	0.00
Alamo clay	60	0.12	75	0.00
Atwater loamy sand	60	6.25	90	1.00
Greenfield sandy loam	72	3.75	90	1.00
Lewis loam	60	1.02	60	0.00
Ramona sandy loam	60	2.59	90	1.00
Ramona sandy loam w/H	60	2.59	90	0.00
Atwater loamy sand w/H	60	6.25	90	0.00
Chino clay loam	64	3.46	90	1.00
Calhi loamy sand w/H	60	7.50	40	0.00
Calhi loamy sand	60	7.50	40	1.00
Fresno and El Peco loams	60	1.27	30	0.00
Artois loam	60	1.27	90	1.00
Artois gravelly loam	60	1.27	90	1.00
Cortina gravelly loam	60	10.00	80	1.00
Hillgate clay loam	54	1.27	80	1.00
Myers clay	60	0.12	100	1.00
Pleasanton gravelly loam	54	0.50	70	1.00
Pleasanton very gravelly sandy loam	54	0.50	70	1.00
Delano sandy loam	63	3.09	70	1.00
Zerker loam	62	1.10	70	1.00
Chanac clay loam	60	1.10	70	1.00
Wasco sandy loam	60	4.00	80	1.00
Borden loam	60	1.35	85	1.00
Grangeville sandy loam	60	3.75	70	1.00
Greenfield coarse sandy loam	60	3.75	100	1.00
Dinuba-El Peco fine sandy loams	60	2.52	55	1.00
Arbuckle gravelly loam	60	1.64	60	1.00
Corning gravelly loam	60	1.64	60	1.00
Cortina very gravelly sandy loam	60	10.00	70	1.00
Kimball loam	60	1.64	90	0.00
Kimball gravelly loam	60	1.64	90	1.00
Hillgate loam	54	1.64	60	1.00
Tehama loam	60	1.64	70	1.00
Tehama silt loam	60	0.12	90	1.00
Hillgate gravelly loam	54	1.64	60	1.00
Wyo gravelly loam	60	3.75	100	1.00
Sycamore complex	44	1.10	80	1.00
Sycamore silty loam	60	1.31	60	1.00
Maria silt loam	60	1.31	60	1.00
Merritt silty clay loam	42	0.41	60	1.00
Pescadero silty clay	40	0.12	50	1.00
Laugenour very fine sandy loam	20	4.15	70	1.00
Willows clay	60	0.12	60	1.00
Nacimiento-Newville complex	35	1.27	80	1.00
Newville gravelly loam	56	1.64	70	1.00
Newville-Dibble-gullied land complex	56	1.27	70	1.00
Wyo loam	42	3.75	100	1.00
Cortina complex	72	10.00	80	1.00
Orland loam	60	1.64	80	1.00
Perkins-Kimball gravelly loams	60	1.10	70	1.00
Arbuckle-Tehama complex	60	1.31	80	1.00
Altamont-Dibble complex	52	0.33	80	1.00
Capay silty clay	60	0.12	80	1.00
Ocraig very stony coarse sandy loam	8	4.00	90	1.00
Olashes sandy loam	60	10.10	100	1.00
Palls-Stohlman stony sandy loams	31	4.00	90	1.00
San Joaquin loam	29	1.00	75	0.00
Hollenbeck silty clay loam	65	0.33	80	1.00
Conejo loam	65	1.10	100	1.00
Conejo-Tisdale complex	42	1.10	75	1.00
Tisdale clay loam	31	0.40	75	1.00
Gridley clay loam	37	0.33	75	1.00
Marcum-Gridley clay loams	43	0.33	75	1.00
Antioch-San Ysidro complex	19	0.38	70	1.00
Capay silty clay loam	60	0.12	70	1.00
Capay clay	60	0.12	70	1.00

Pescadero clay loam	34	0.12	40	1.00
Yolo silty clay loam	36	0.41	70	1.00
Fresno, El Peco, and Chino soils	64	3.17	60	0.00
Fresno and El Peco fine sandy loams	63	1.27	30	0.00
Tujunga loamy sand	67	13.00	100	1.00
Borden fine sandy loam	60	1.35	70	1.00
Pachappa sandy loam	63	3.46	80	1.00
Cajon loamy sand	63	13.00	70	1.00
San Joaquin-Alamo complex	60	1.02	80	1.00
Trigo fine sandy loam	16	13.00	75	1.00
Cometa sandy loam	60	1.02	80	1.00
Hanford sandy loam w/H	60	3.75	90	1.00
Montpellier coarse sandy loam	60	3.02	80	1.00
Whitney and Rocklin sandy loams	36	11.00	70	1.00
Whitney fine sandy loam	28	13.00	90	1.00
Greenfield sandy loam w/H	72	3.75	90	0.00
Hollenbeck silty clay	60	0.33	80	0.00
Jacktone clay	60	0.33	70	0.00
Manteca fine sandy loam	74	3.29	70	0.00
Stockton clay	60	0.12	70	0.00
Chualar sandy loam	72	0.50	80	1.00
Delhi loamy sand	60	13.00	90	1.00
Delhi sand	60	13.00	90	1.00
Dello loamy sand	60	13.00	80	1.00
Dinuba sandy loam	60	13.00	75	1.00
Dinuba fine sandy loam	60	13.00	75	1.00
Fresno fine sandy loam	63	1.27	65	0.00
Modesto clay loam	62	0.40	80	1.00
Modesto loam	62	0.40	80	1.00
Meikle clay	60	0.03	90	1.00
Hanford sandy loam	60	4.15	80	1.00
Hilmar loamy sand	66	10.02	60	1.00
Oakdale sandy loam	70	3.46	100	1.00
Waukena fine sandy loam	61	1.27	60	1.00
Rocklin sandy loam	60	2.52	60	0.00
Hopeton clay loam	38	0.40	75	1.00
Madera sandy loam	60	0.12	65	0.00
Whitney sandy loam	31	13.00	80	1.00
Hanford fine sandy loam	60	4.15	80	1.00
Wyman clay loam	60	3.09	80	1.00
Bear Creek clay loam	53	0.03	90	1.00
Honcut clay loam	60	0.03	80	1.00
Cajon coarse sandy loam	60	7.50	50	1.00
Fresno sandy loam	63	2.59	50	0.00
Fresno clay loam	63	2.59	50	0.00
Fresno-Traver complex	63	2.52	45	0.00
Hesperia sandy loam	63	2.59	65	1.00
Pond fine sandy loam	60	2.59	30	1.00
Armona loam	60	10.10	50	1.00
Rossi fine sandy loam	65	1.27	30	1.00
Traver sandy loam	60	2.59	30	1.00
Traver fine sandy loam	60	2.59	30	1.00
Boggs sandy loam	60	1.29	50	1.00
Homeland fine sandy loam	60	3.29	60	1.00
Twisselman silty clay	60	1.02	60	1.00
Tulare clay	60	0.05	60	1.00
Westcamp loam	72	1.02	40	1.00
Chino loam	64	2.90	80	1.00
Chino fine sandy loam	60	3.46	80	1.00
Fresno, El Peco, and Pozo soils	60	1.27	45	0.35
Grangeville fine sandy loam	60	3.29	70	1.00
Pachappa fine sandy loam	63	3.46	80	1.00
Pozo loam	36	0.40	80	1.00
Traver loam	64	2.59	20	1.00
Visalia sandy loam	60	6.25	80	1.00
Wunjey very fine sandy loam	66	1.64	50	1.00
Centerville clay	37	0.12	80	1.00
Exeter loam	60	3.09	80	0.00
Havala loam	64	3.09	80	1.00
Buttonwillow clay	64	3.02	60	1.00
Garces loam	60	0.33	50	1.00
Jerryslu loam	60	0.05	50	0.00
Kimberlina fine sandy loam	71	0.35	80	1.00
Lerdo complex	60	0.07	50	1.00
Milham sandy loam	60	0.14	70	1.00
Marguerite loam	60	0.40	90	1.00
Snelling sandy loam	80	13.00	100	1.00
Raynor cobbly clay	48	0.40	100	1.00
Whitney and Rocklin soils	60	11.00	75	1.00
Lewis silty clay loam	60	0.12	60	1.00
Merced clay	60	0.40	80	1.00
Rossi clay	60	0.40	30	1.00
Rossi clay loam	60	0.40	30	1.00
Waukena loam	60	0.12	60	1.00
Panoche clay loam	60	0.40	50	1.00

Appendix C: Soil Area Data by Site

The percent area each soil makes up out of the total site area is listed below. Together with the information in Appendix D, this information was used to determine the Soils Sub-Index results given in Section 4.

Sacramento Valley

Site ID	Soil	%
Thomes Creek	Arbuckle gravelly loam	20.7
	Arbuckle-Tehama complex	0.1
	Corning gravelly loam	31.5
	Cortina complex	1
	Hillgate loam	7.9
	Nacimiento-Newville complex	9.7
	Newville gravelly loam	26.9
	Newville-Dibble-gullied land complex	0.4
	Orland loam	0.9
	Perkins-Kimball gravelly loams	0.1
	Tehama loam	0.6
	Wyo loam	0.3
Burch Creek	Altamont clay	6.5
	Clear Lake clay	0.1
	Corning gravelly loam	13.6
	Cortina gravelly fine sandy loam	1
	Hillgate loam	20.8
	Kimball gravelly loam	30.7
	Kimball loam	7.8
	Maywood loam	0.4
	Perkins gravelly loam	3.7
Stone Valley	Altamont clay	3.8
	Artois loam	0.9
	Capay clay	2.1
	Cortina gravelly loam	2.1
	Cortina very gravelly sandy loam	9.4
	Hillgate gravelly loam	0.7
	Hillgate loam	18.1
	Maywood loam	1.9
	Myers clay	0.5
	Tehama loam	6
	Tehama silt loam	54.4
	Zamora silty clay loam	0.2
Stoney Creek Fan	Arbuckle gravelly loam	56.9
	Corning gravelly loam	0.1
	Cortina very gravelly sandy loam	4.3
	Hillgate loam	1.9
	Kimball gravelly loam	3.5
Stoney Creek Fan (...cont'd)	Kimball loam	14.4
	Tehama loam	2.2
	Tehama silt loam	16.7
	Wyo gravelly loam	0.1
Sutter Buttes	Altamont-Dibble complex	5.8
	Ocraig very stony course sandy loam	7.6
	Olashes sandy loam	9.1
	Palls-Stohlman stony sandy loams	77.4
Yuba City	Conejo loam	10.3
	Conejo-Tisdale complex	56.8
	Gridley clay loam	3.5
	Live oak sandy clay loam	1.8
	Marcum-Gridley clay loams	16.6
	Tisdale clay loam	11
American Basin	Exeter sandy loam	13.7
	Galt clay	4.1
	Marcum clay loam	1.9
	San Joaquin sandy loam	56.7
	San Joaquin-Arents-Durochrepts complex	23.6
Best Slough	Conejo loam	3.7
	Hollenbeck silty clay loam	26.9
	Kimball loam	0.1
	San Joaquin loam	69.2
Elk Grove	Bruella sandy loam	4.9
	Galt clay	5.6
	Galt-urban land complex	0.5
	Madera-Galt complex	0.3
	San Joaquin silt loam	53.1
	San Joaquin-Galt complex	34.8
	San Joaquin-urban land complex	0.7
	San Joaquin-Xerarents complex	0.2
Galt	Corning complex	94.6
	Redding gravelly loam	0.9
	Redding loam	4.5
South Fork Putah Creek	Antioch-San Ysidro complex	4.4
	Capay clay	40.7
	Capay silty clay loam	32.5
	Clear Lake clay	0.1
	Pescadero clay loam	16.6
	Yolo silty clay loam	5.7

San Joaquin Valley

Site	Soil	%
Mormon Slough	Galt clay	16.7
	Hollenbeck silty clay	52.2
	Jacktone clay	23.6
	Manteca fine sandy loam	1
	Stockton clay	6.5
Dry Creek	Bear Creek clay loam	1.2
	Dinuba fine sandy loam	0.9
	Greenfield sandy loam	12.7
	Greenfield sandy loam w/H	0.3
	Hanford fine sandy loam	31.5
	Hanford sandy loam	46.3
	Honcut clay loam	0.2
	Madera sandy loam	0.2
	Oakdale sandy loam	1.1
	Terrace escarpments	3
	Tujunga loamy sand	1.4
	Wyman clay loam	1.2
Montpellier	Greenfield sandy loam	1.8
	Hopeton clay loam	7.4
	Madera sandy loam	1.5
	Montpellier coarse sandy loam	0.4
	Rocklin sandy loam	13.7
	Whitney and Rocklin sandy loams	26.2
	Whitney sandy loam	49
Owens Creek	Lewis silty clay loam	32.9
	Merced clay	0.3
	Rossi clay	18
	Rossi clay loam	44.5
	Waukena loam	4.4
Dutchman Creek	Alamo clay	0.6
	Greenfield sandy loam	0.5
	Madera fine sandy loam	0.2
	Madera sandy loam	33.7
	Marguerite loam	1.9
	Raynor cobbly clay	0.2
	Redding gravelly loam	0.4
	San Joaquin loam	21.8
	San Joaquin sandy loam	20
	San Joaquin-Alamo complex	10.4
	Snelling sandy loam	4.7
	Whitney and Rocklin soils	4.5
	Whitney sandy loam	1.1
Berenda Creek	Alamo clay	0.2
	Atwater loamy sand	0.2
	Atwater loamy sand w/H	7.3
	Greenfield sandy loam	2.7
Berenda Creek (...cont'd)	Lewis loam	0.1
	Madera fine sandy loam	67
	Madera loam	9.2
	Madera-Alamo complex	1.5
	Ramona sandy loam	8.3
	Ramona sandy loam w/H	2.6
Chowchilla Bypass	Chino clay loam	0.6
	Chino fine sandy loam	3.3
	Chino loam	13.9
	Fresno and El Peco fine sandy loams	6.9
	Fresno and El Peco loams	34.8
	Fresno, El Peco, and Chino soils	2.1
	Fresno, El Peco, and Pozo soils	5
	Grangeville fine sandy loam	3.7
	Pachappa fine sandy loam	1.8
	Pachappa sandy loam	1.8
	Pozo loam	18
	Traver loam	6.8
	Visalia sandy loam	0.6
	Wunjey very fine sandy loam	0.7
Gravelly Ford	Borden loam	7.2
	Dinuba-El Peco fine sandy loams	14.9
	Fresno and El Peco fine sandy loams	7.2
	Fresno and El Peco loams	4.6
	Grangeville fine sandy loam	3.8
	Grangeville sandy loam	0
	Greenfield coarse sandy loam	0
	Hanford sandy loam	2.6
	Pachappa fine sandy loam	25.8
	Traver loam	28.5
	Tujunga loamy sand	4.6
Little Dry Creek	Alamo clay	0.6
	Atwater loamy sand	10.5
	Atwater loamy sand w/H	0.7
	Cometa sandy loam	1.5
	Greenfield sandy loam	0.5
	Greenfield sandy loam w/H	3.4
	Hanford sandy loam w/H	6.7
	Montpellier coarse sandy loam	0.2
	Ramona sandy loam	4
	San Joaquin sandy loam	40.1
	San Joaquin-Alamo complex	0.8
	Trigo fine sandy loam	0.8
	Whitney and Rocklin sandy loams	26.8
	Whitney fine sandy loam	3.6

James Bypass	Cajon coarse sandy loam	3.4
	Calhi loamy sand	5.8
	Fresno clay loam	23.4
	Fresno fine sandy loam	31.6
	Fresno sandy loam	19.4
	Fresno-Traver complex	5.3
	Hesperia sandy loam	0.5
	Pond fine sandy loam	3.7
	Rossi fine sandy loam	0.3
	Traver fine sandy loam	0.4
	Traver sandy loam	4.6
White River	Centerville clay	79.7
	Exeter loam	14.8
	Havala loam	5.4
Semitropic Ridge	Chanac clay loam	16.6
	Delano sandy loam	69
	Wasco sandy loam	2.9
	Zerker loam	11.5
Arvin-Edison	Kimberlina fine sandy loam	81
	Panoche clay loam	19

Appendix D: Water storage volumes used in the San Joaquin Valley hydrologic connectivity sub-index

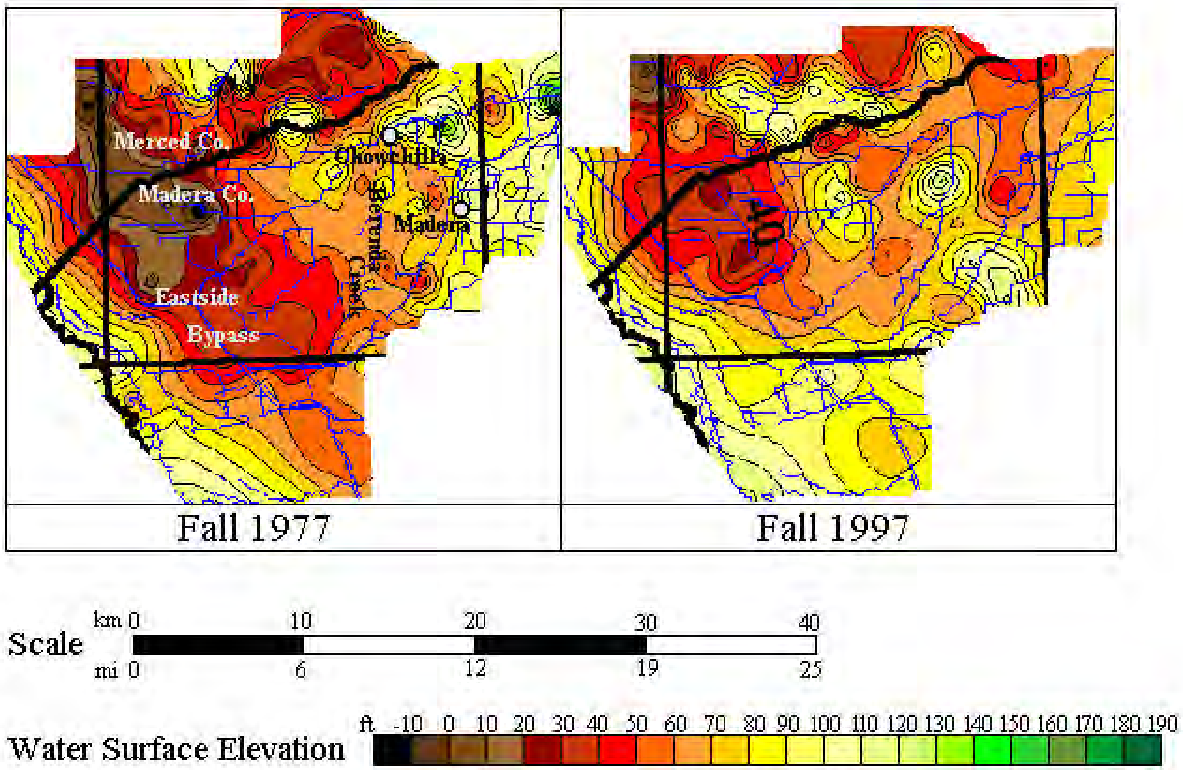
All values reported in million acre-feet

Site	Fall 1977	Spring 1997	Fall 1997
Allensworth	1.30	5.96	7.77
Arvin-Edison	1.01	1.11	1.55
Berenda Creek	0.00	0.19	0.06
Chowchilla Bypass	0.03	0.53	0.32
Dry Creek	0.02	0.00	0.00
Dutchman Creek	0.91	1.41	1.54
Gravelly Ford	3.61	3.38	2.04
Hetch Hetchy Aqueduct	0.00	0.01	0.01
James Bypass	6.13	2.50	5.01
Kern Water Bank	13.05	14.45	21.61
Little Dry Creek	0.28	1.29	4.37
Montpellier	1.04	0.31	0.81
Mormon Slough	5.19	0.79	1.71
Owens Creek	0.79	0.44	0.59
Semitropic Ridge	6.07	0.89	1.30
White River	1.29	0.15	0.70

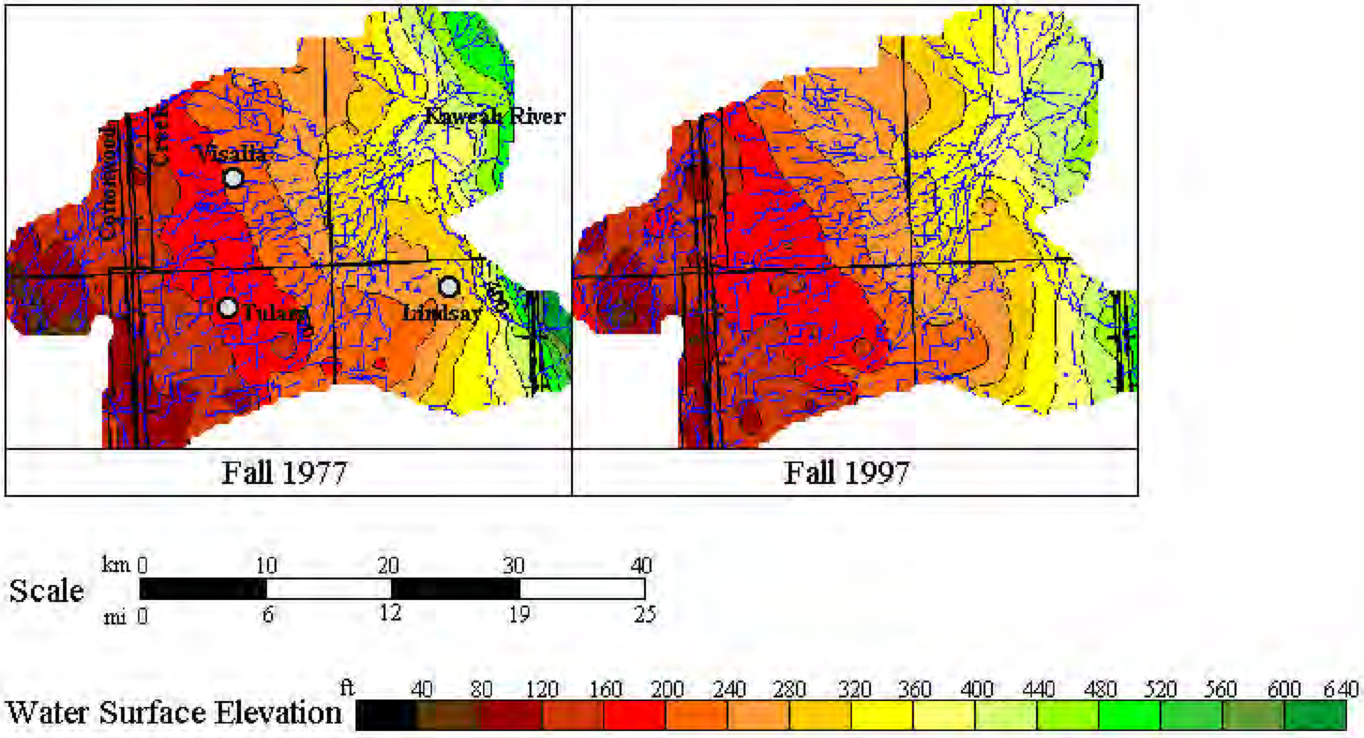
Appendix E: Basin Maps

The following maps show water surface contours for each of the basins in the San Joaquin Valley in Fall 1977 and in Fall 1997.

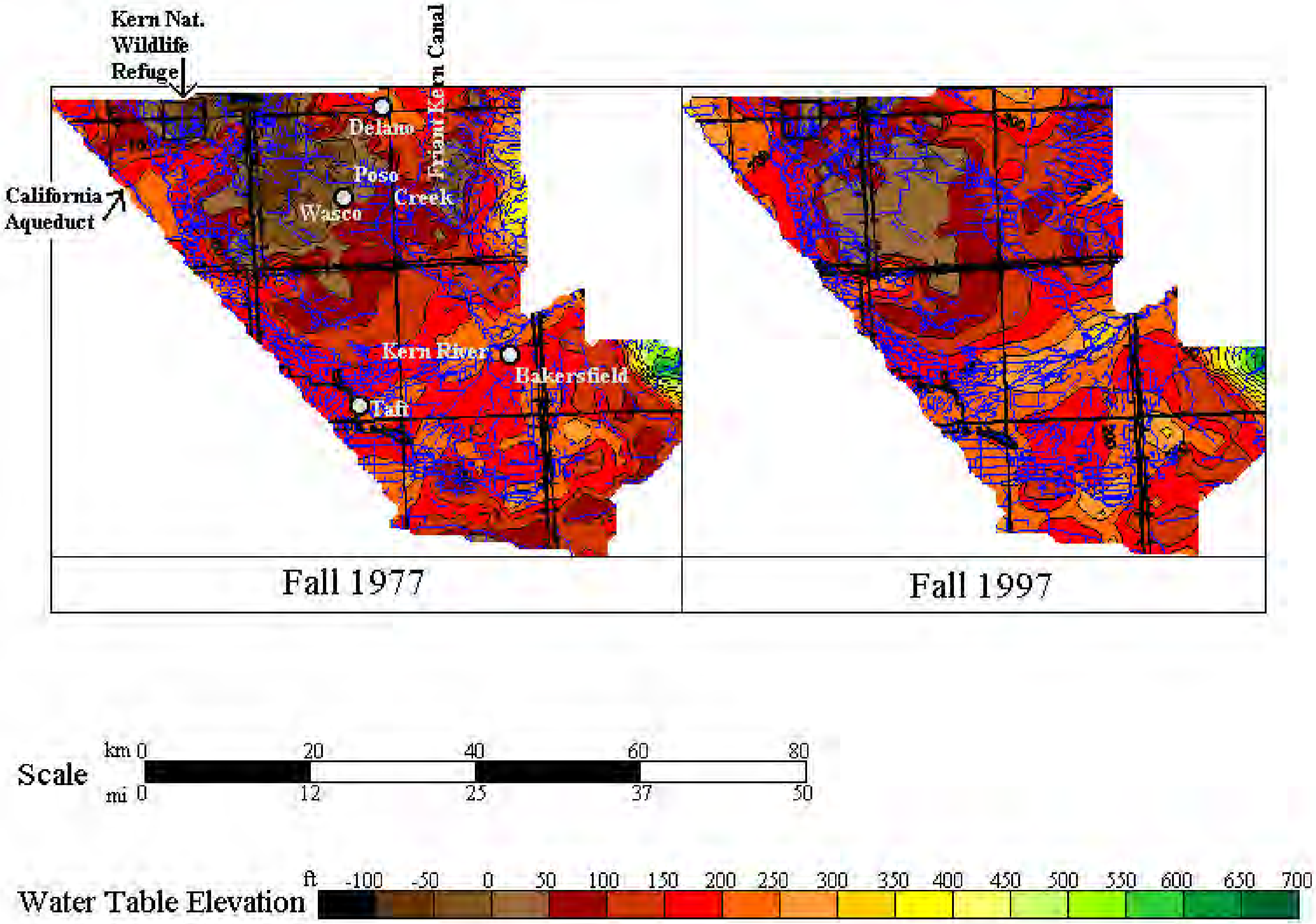
Chowchilla Basin



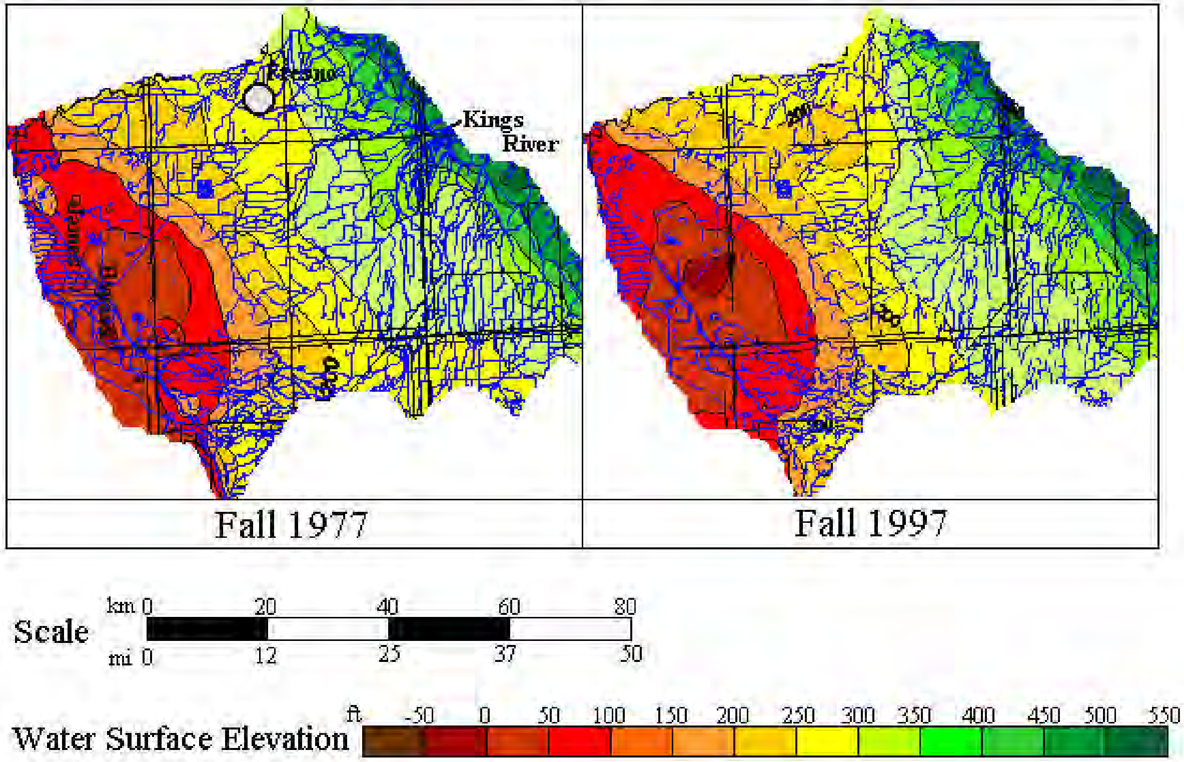
Kaweah Basin



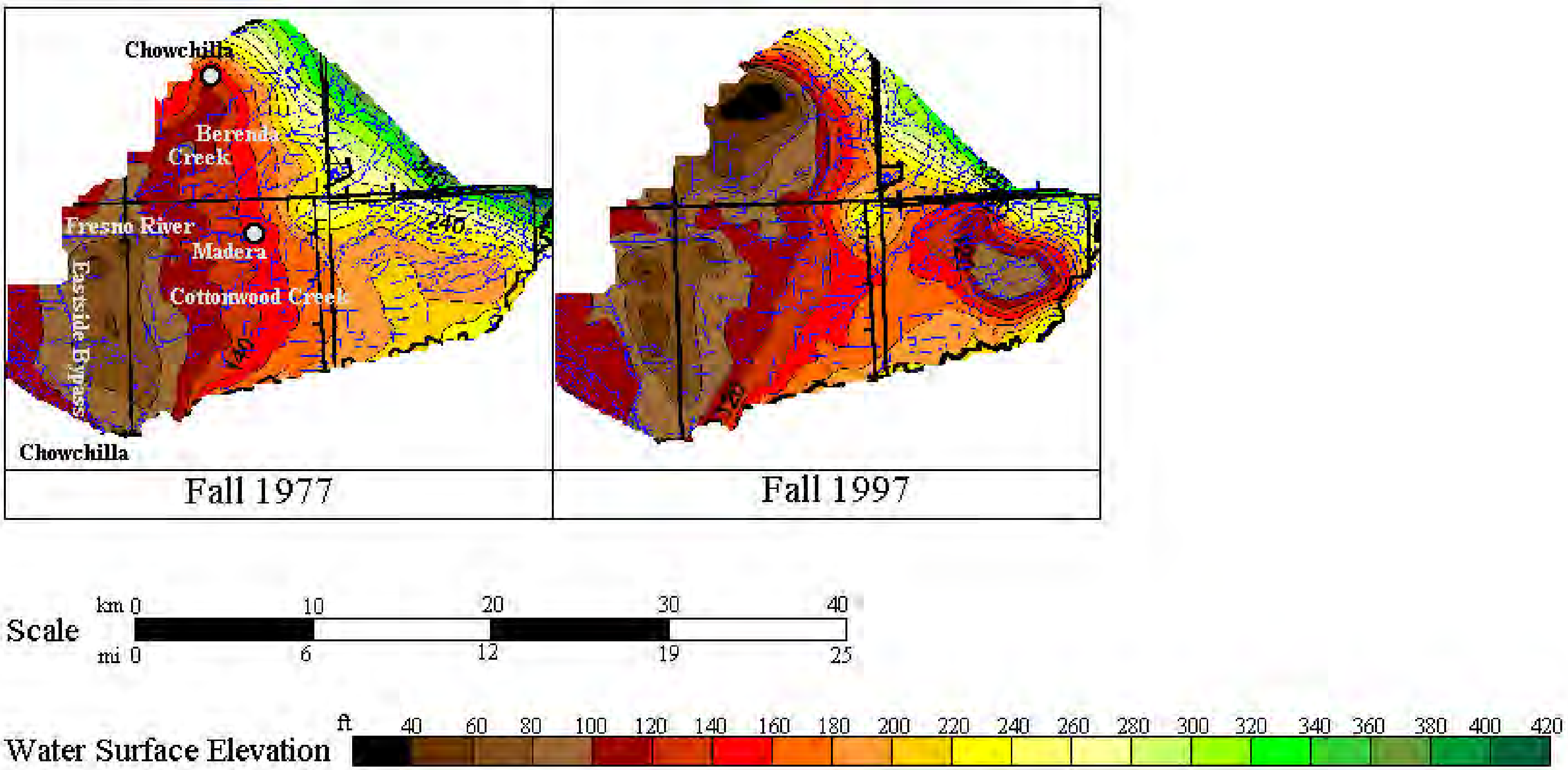
Kern Basin


Kern Nat.
Wildlife
Refuge
California
Aqueduct
Friant Kern Canal
Delano
Poso
Creek
Wasco
Kern River
Bakersfield
Taft
Fall 1977
Fall 1997
Scale
km 0
20
40
60
80
mi 0
12
25
37
50
Water Table Elevation
ft
-100
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700

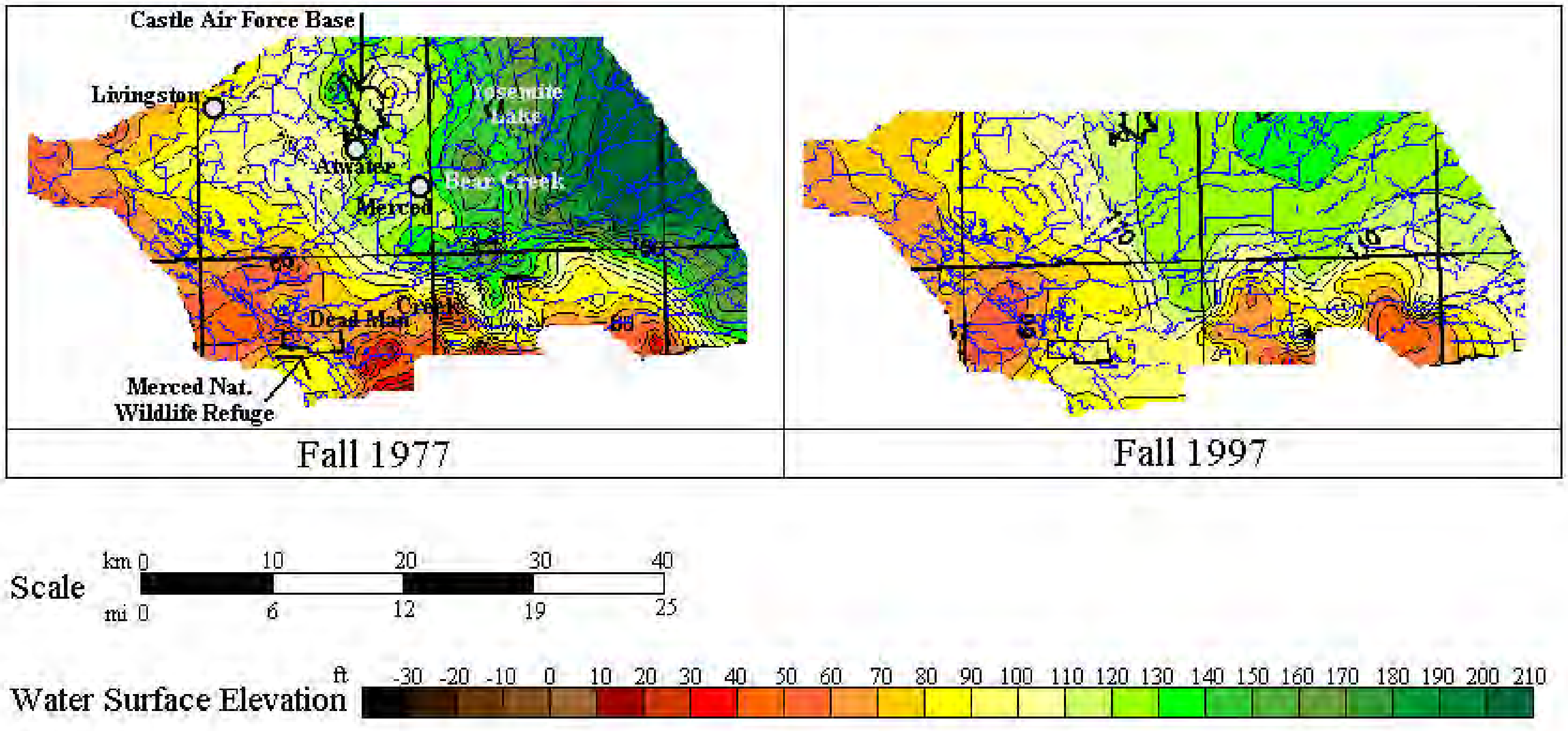
Kings Basin


Fresno
Kings River
James
Burrel
200
300
Fall 1977
Fall 1997
Scale
km 0 20 40 60 80
mi 0 12 25 37 50
Water Surface Elevation
ft
-50
0
50
100
150
200
250
300
350
400
450
500
550

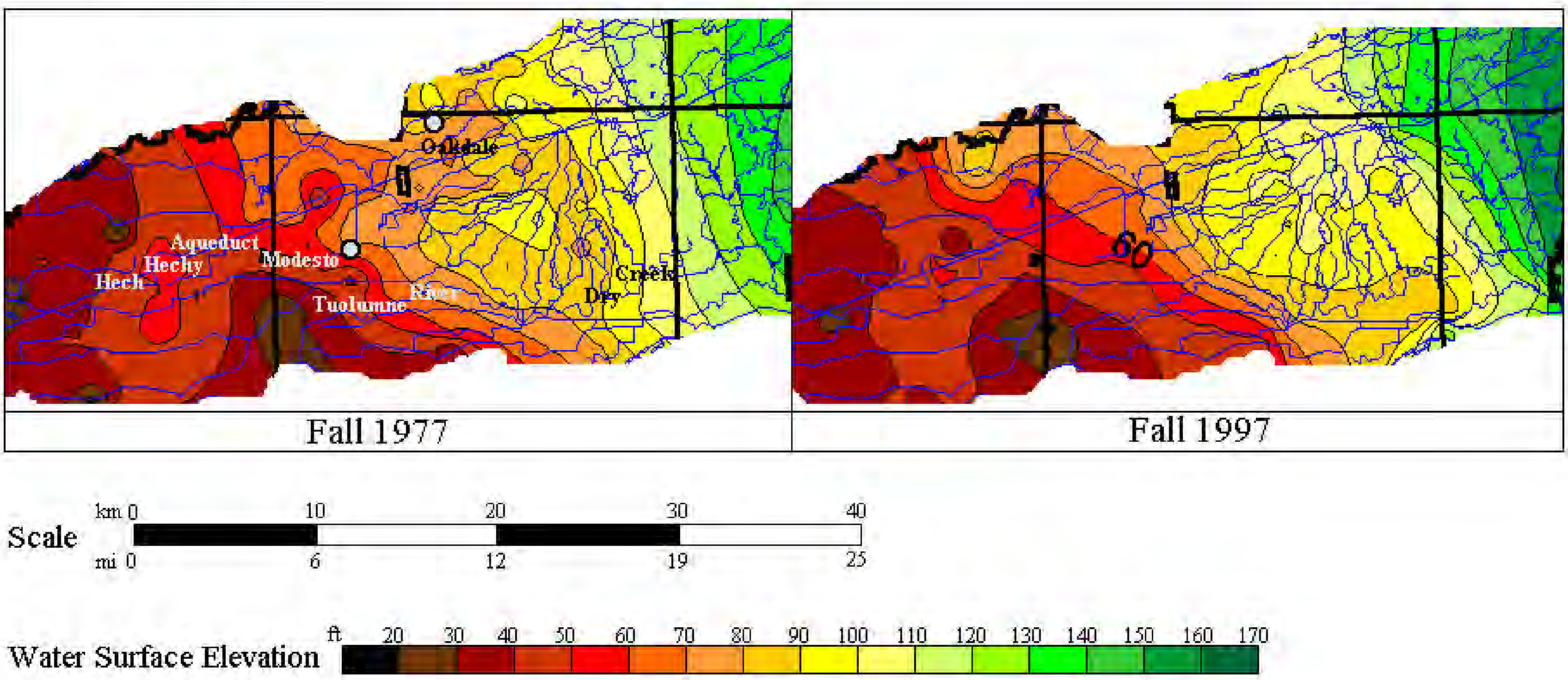
Madera Basin



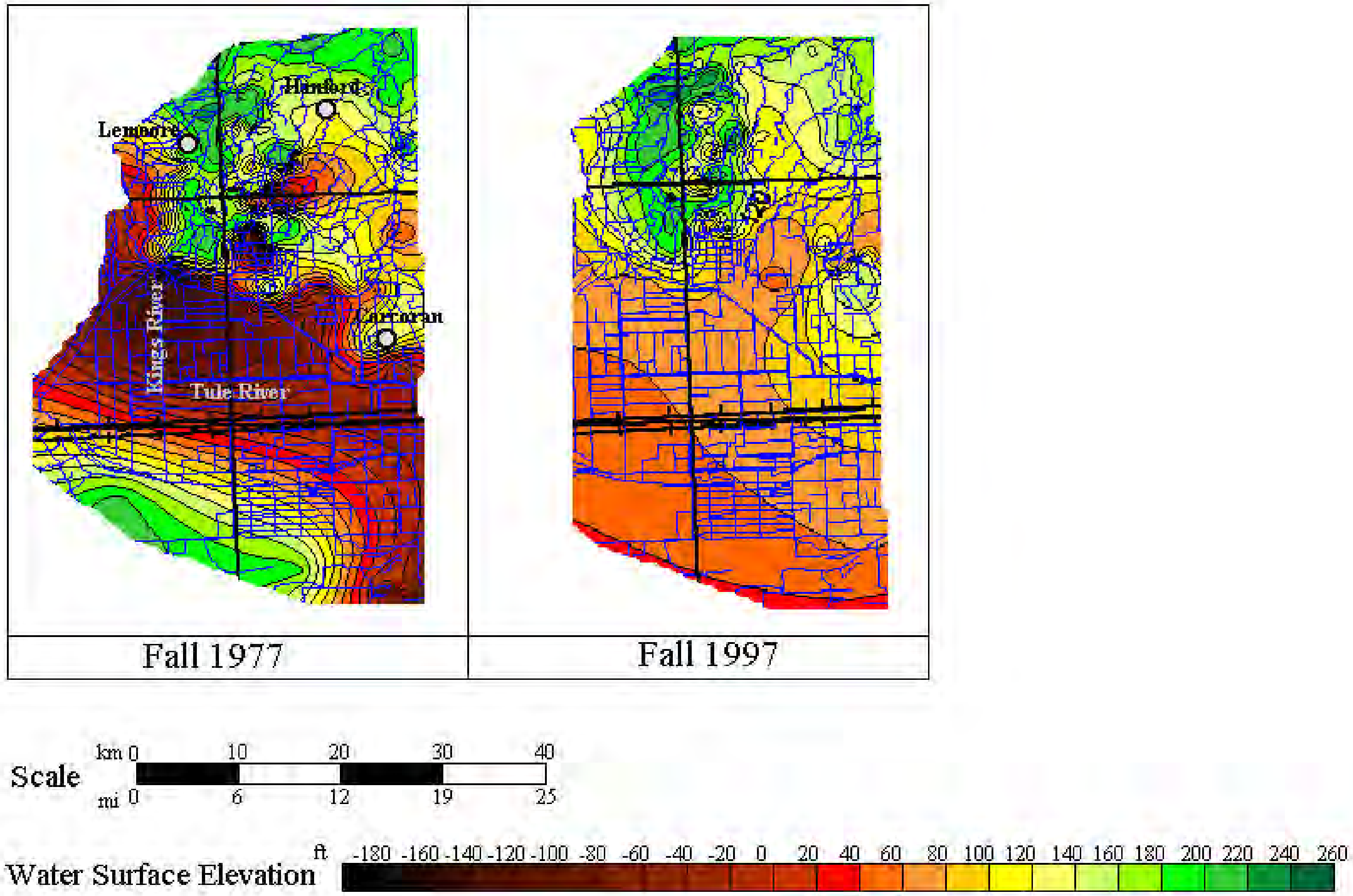
Merced Basin



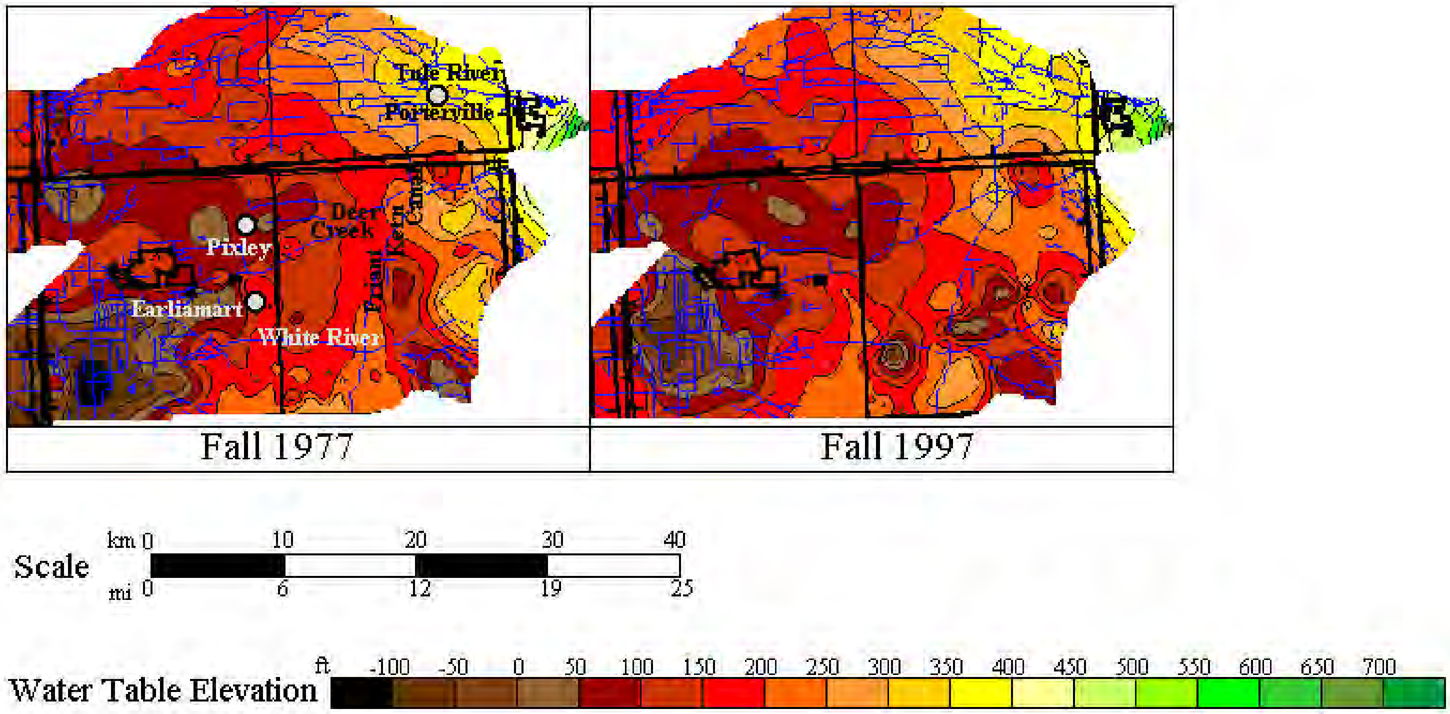
Modesto Basin



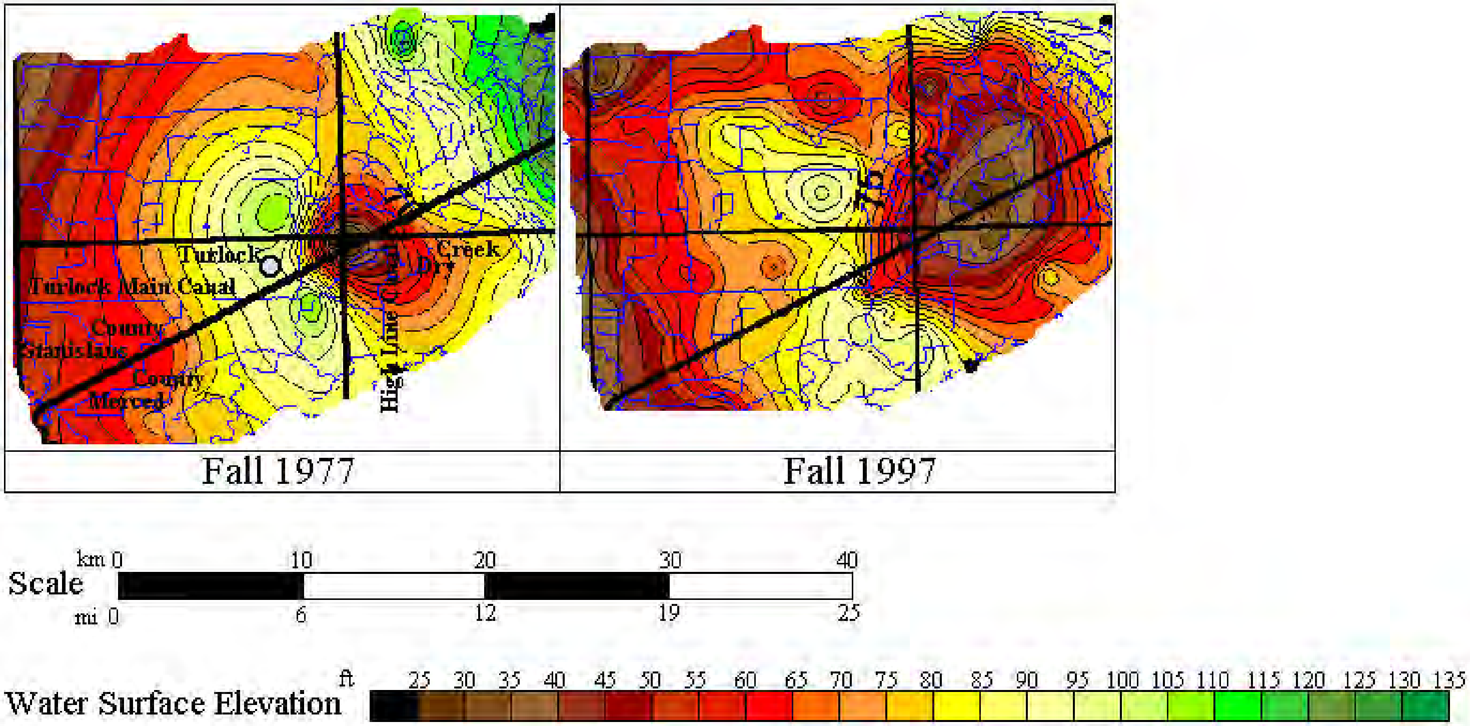
Tulare Lake Basin



Tule Basin


Tule River
Porterville
Deer Creek
Pixley
Friant Kern Canal
Earliamart
White River
Fall 1977
Fall 1997
Scale
km 0 10 20 30 40
mi 0 6 12 19 25
Water Table Elevation
ft -100 -50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700

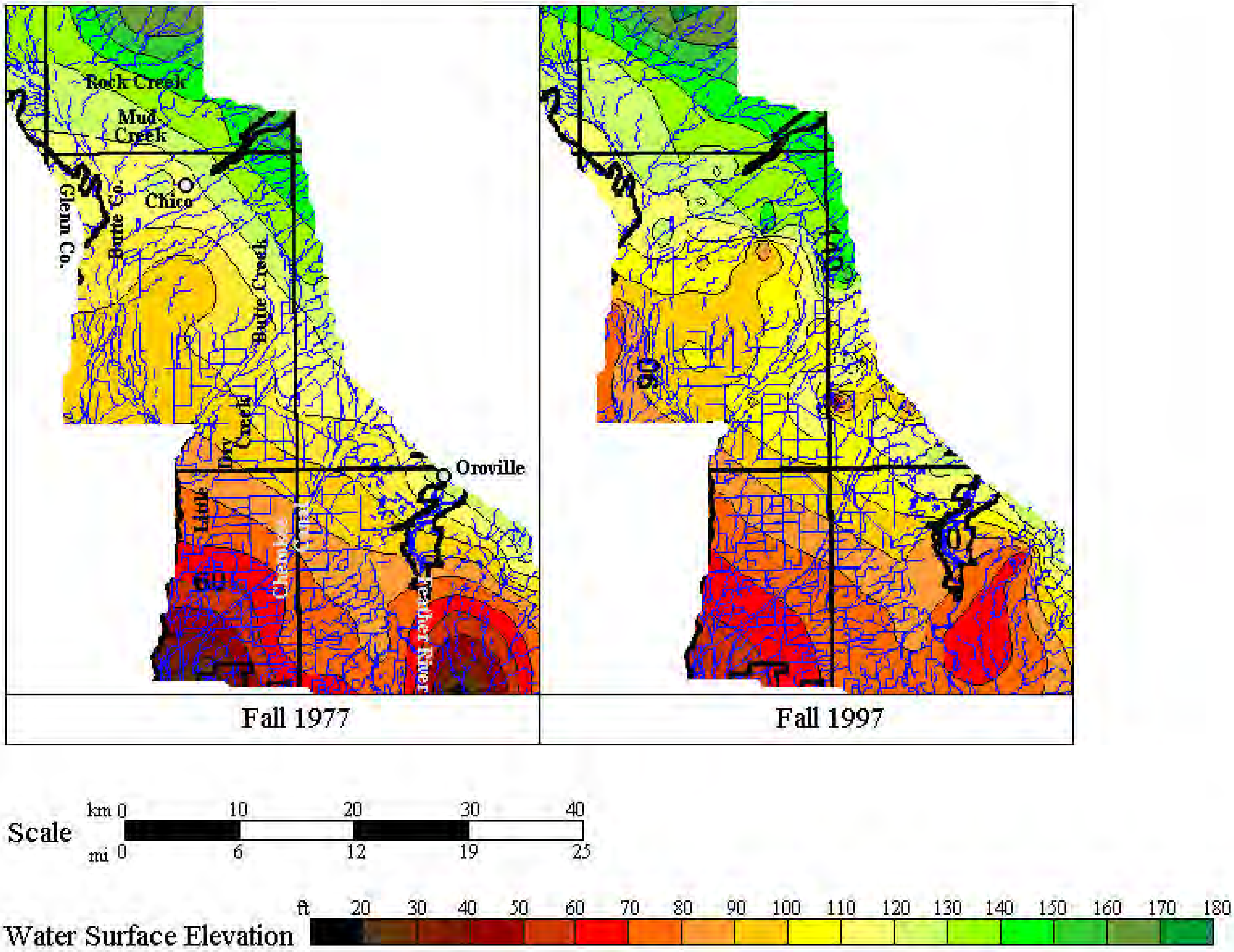
Turlock Basin



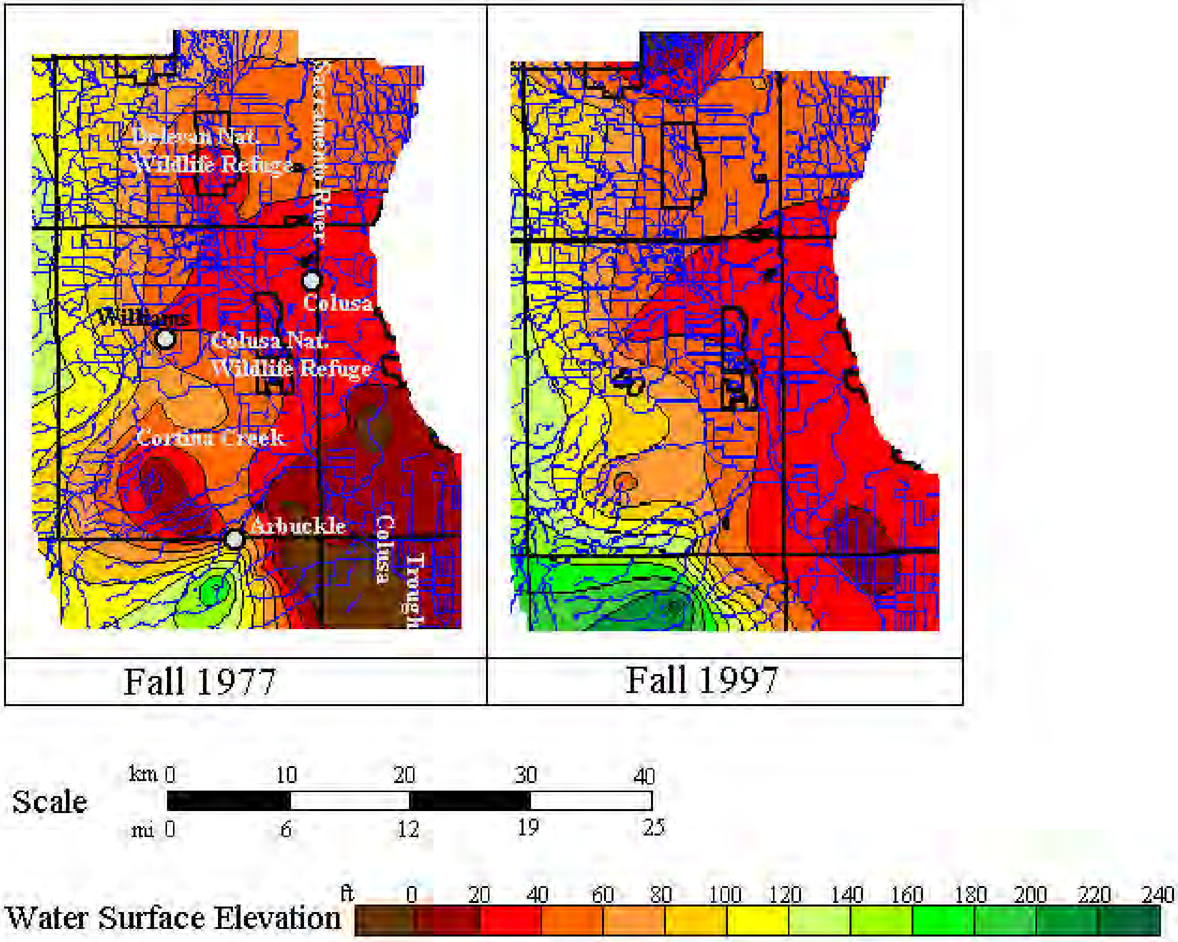
Appendix F: Basin Maps

Even though the Sacramento Valley index did not include a Hydrologic Conductivity Sub-Index, we have included the water basin maps for Fall 1977 and Fall 1997 for comparative purposes.

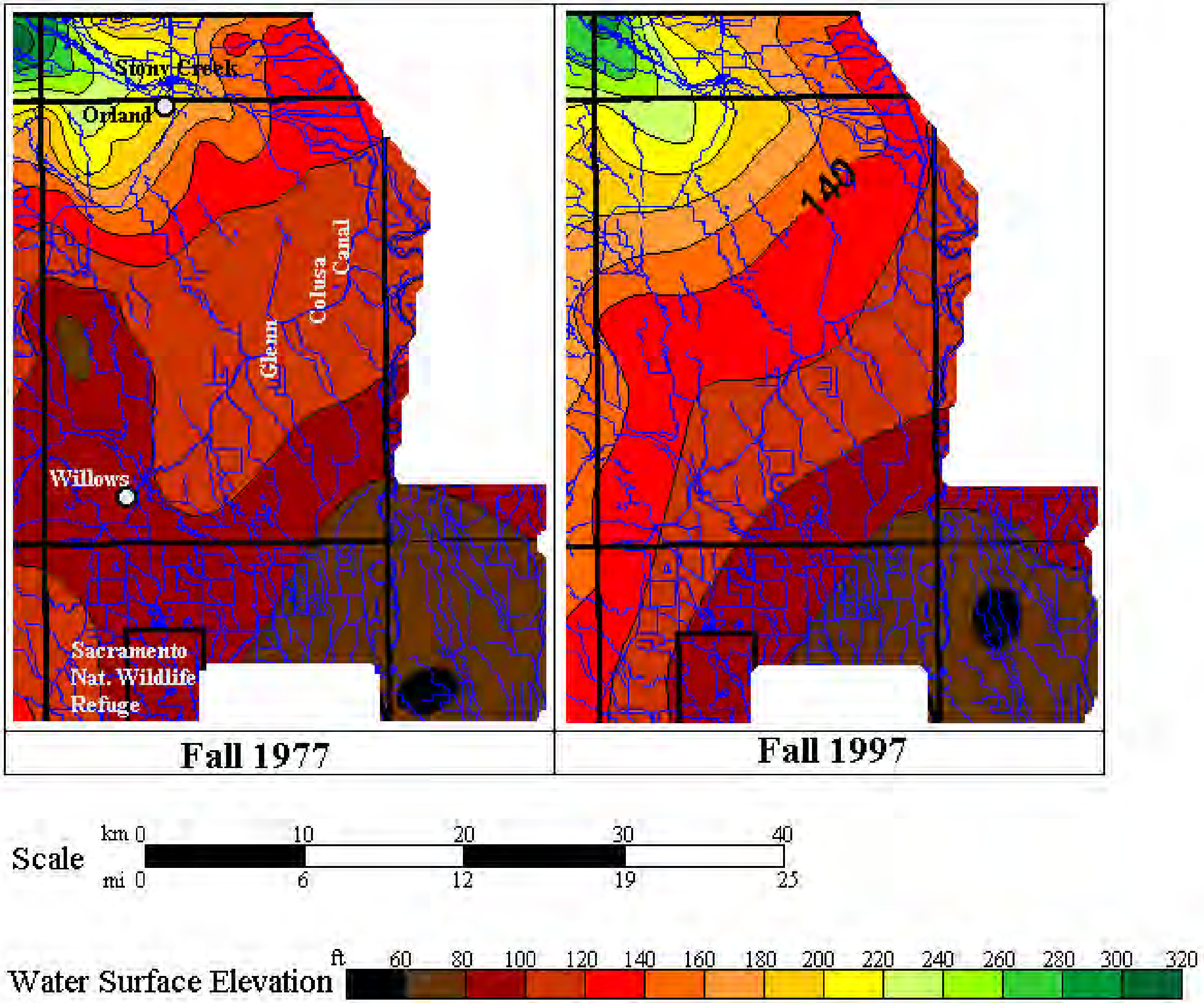
Butte Basin


Rock Creek
Mud Creek
Chico
Glenn Co.
Butte Co.
Butte Creek
Little
Dry
Creek
Cherokee Canal
Oroville
Feather River
60
90
110
Fall 1977
Fall 1997
Scale
km 0 10 20 30 40
mi 0 6 12 19 25
Water Surface Elevation
ft 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180

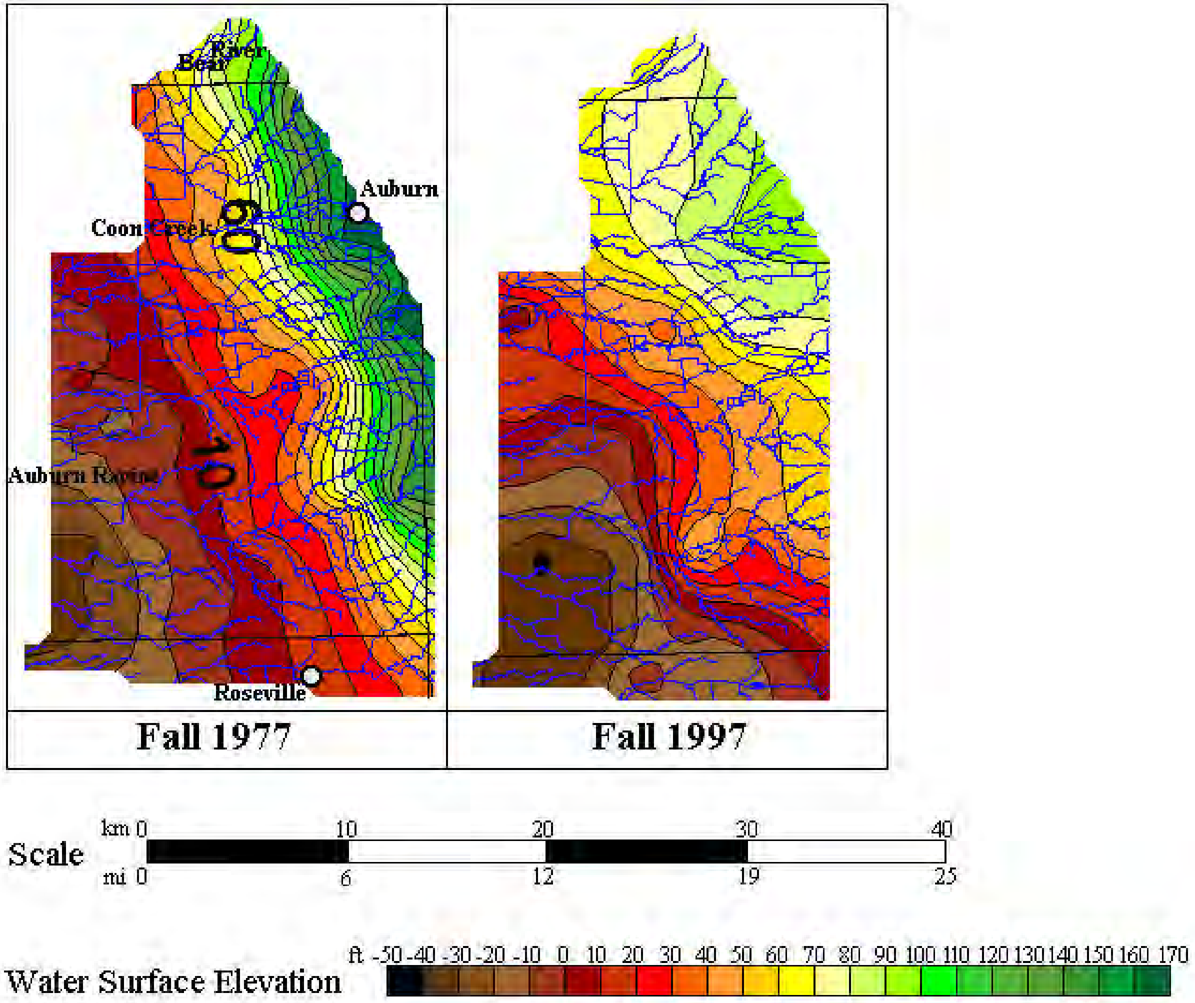
Colusa Basin



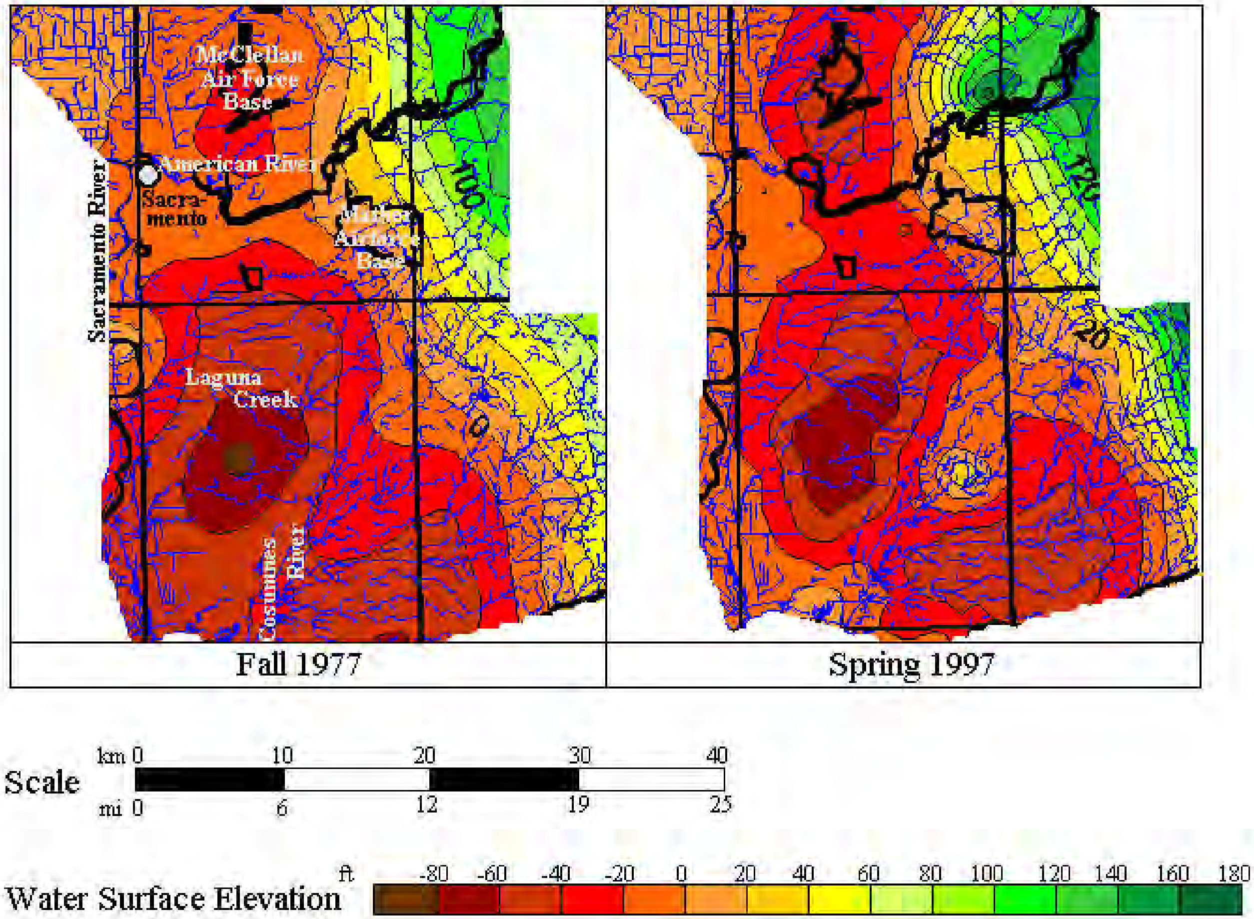
Glenn Basin


Stony Creek
Orland
Colusa
Canal
Glenn
Willows
Sacramento
Nat. Wildlife
Refuge
140
Fall 1977
Fall 1997
Scale
km 0
10
20
30
40
mi 0
6
12
19
25
Water Surface Elevation
ft
60
80
100
120
140
160
180
200
220
240
260
280
300
320

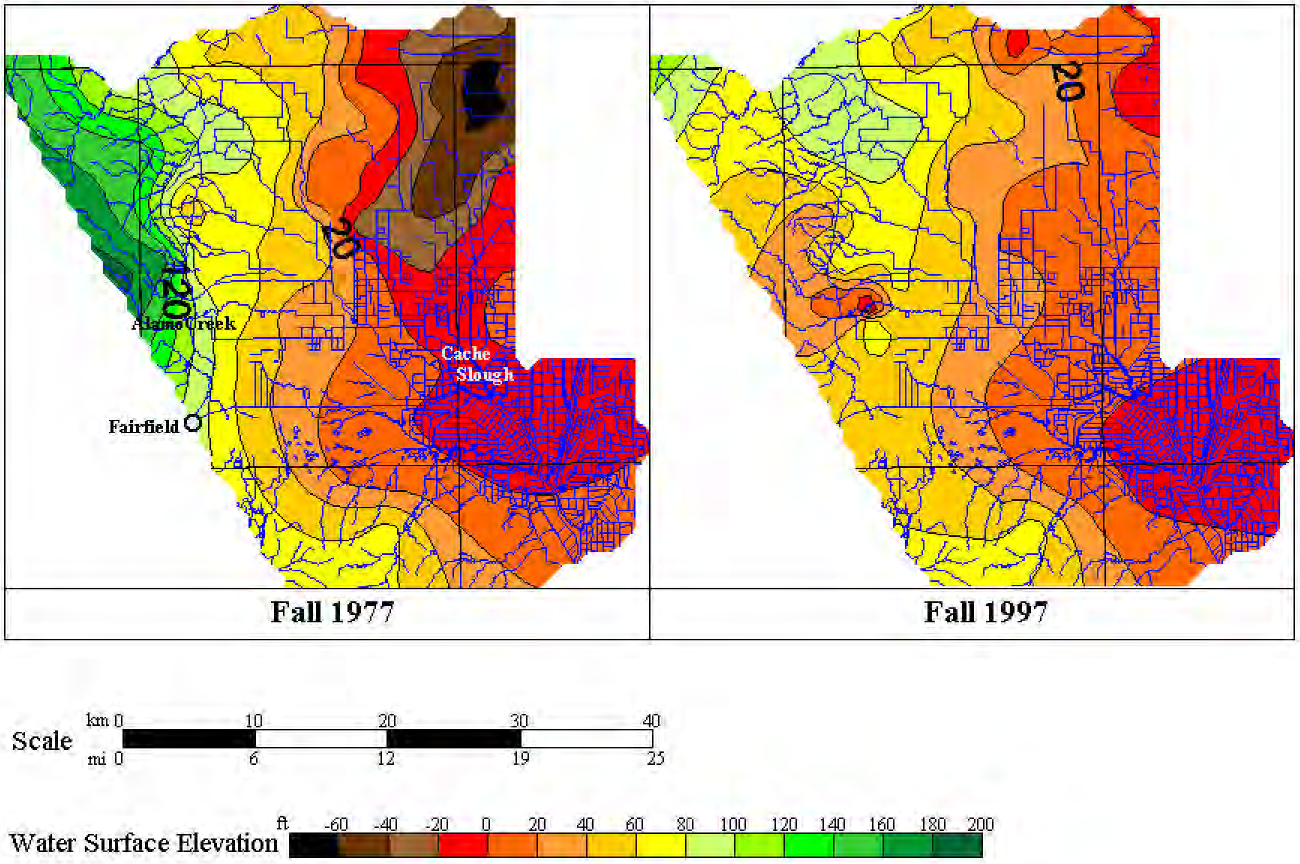
Placer Basin



Sacramento Basin



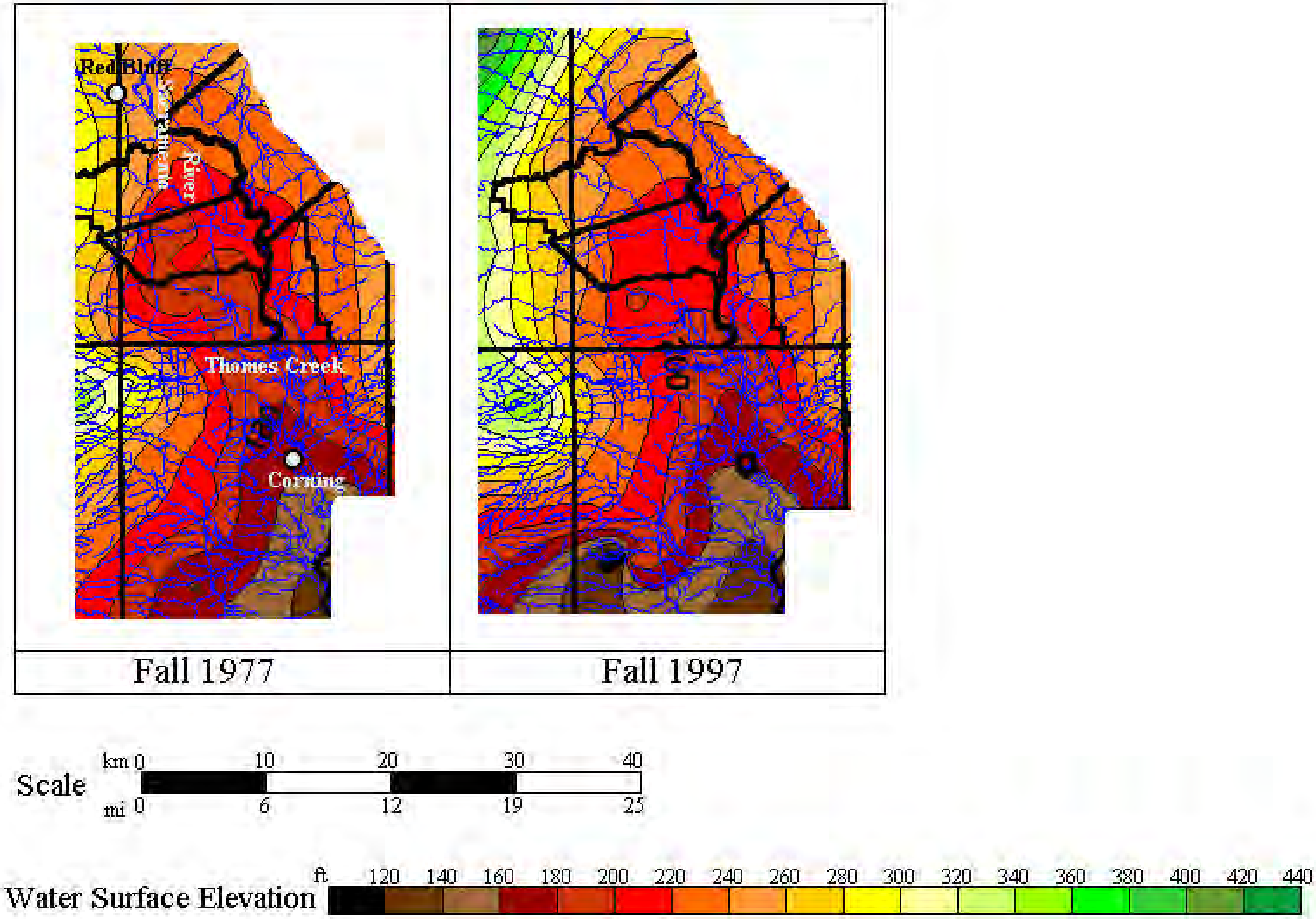
Solano Basin



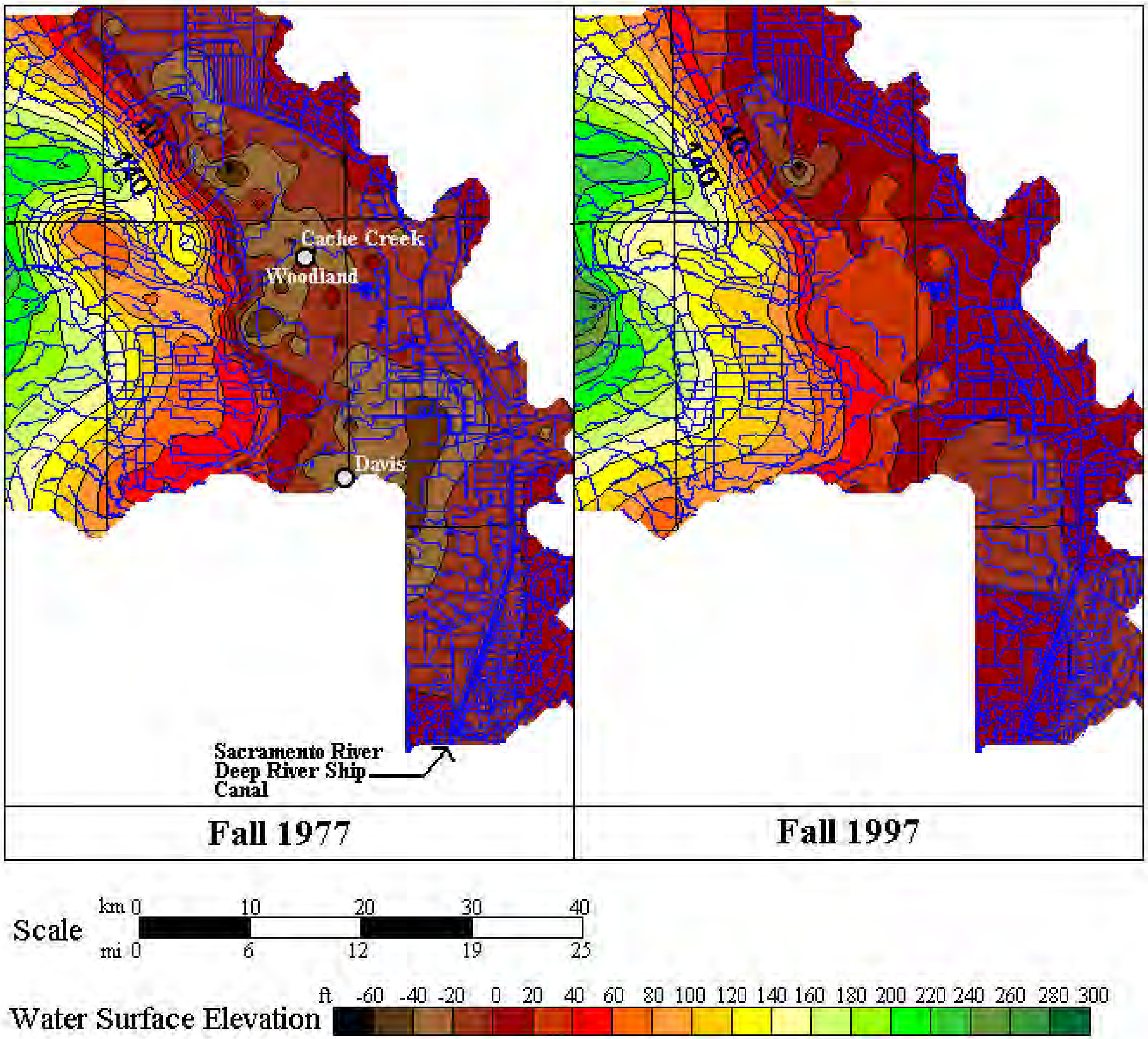
Fall 1977

Fall 1997

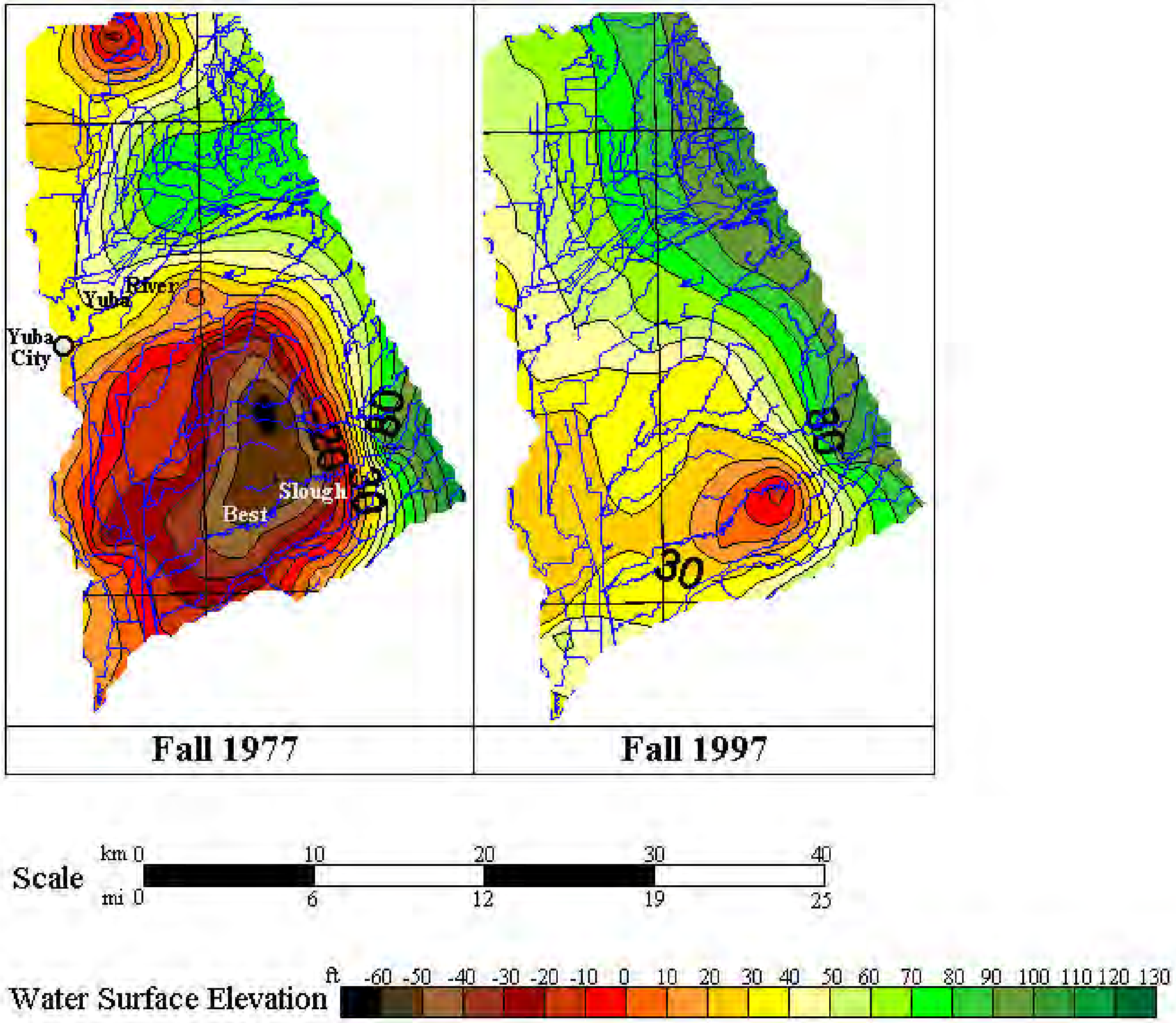
Tehama Basin



Yolo Basin


40
140
Cache Creek
Woodland
Davis
Sacramento River Deep River Ship Canal
Fall 1977
Fall 1997
Scale
km 0 10 20 30 40
mi 0 6 12 19 25
Water Surface Elevation
ft -60 -40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300

Yuba Basin


Yuba City
Yuba River
Best Slough
20
30
80
Fall 1977
30
80
Fall 1997
Scale
km 0 10 20 30 40
mi 0 6 12 19 25
Water Surface Elevation
ft -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 130

BDCP1738.

Natural
Heritage
Institute

Feasibility Study of a Maximal Program of Groundwater Banking

December, 1998

David R. Purkey
Gregory A. Thomas
David K. Fullerton
Marcus Moench
Lee Axelrad

Table of Contents

Acknowledgements

This report would not have been possible without the sustained support of the Ford Foundation. Recognizing the enormous contribution which groundwater banking could make towards diffusing water allocation conflict in California, indeed around the world, Ford was willing to underwrite several years of foundational research. By necessity, this research focused on framing the broad structural considerations and the general legal and institutional tenets of a maximal program of groundwater banking. Thanks to their generous financial assistance, however, we have also succeeded in adding form to the frame. The exciting payoff from the Ford Foundation's investment are the explorations of site-specific details of groundwater banking opportunities which are recounted in this report. Extending this analysis to the full suite of opportunities is now possible.

Our explorations have been facilitated by the availability of the Water Evaluation and Planning system (WEAP). This innovative river basin planning software, developed by the Tellus Institute in Boston, Massachusetts, underwent a major upgrade thanks to the financial support of the CalFed Bay-Delta Program, the U.S. Fish and Wildlife Service, the U.S. Bureau of Reclamation, and the Metropolitan Water District of Southern California. We sincerely appreciate the contribution of each of these valued partners and look forward to additional collaboration in the area of groundwater banking.

Finally, we would like to acknowledge you, the reader, for your willingness to read this document. We cannot promise that it will always make for gripping reading, although we are confident that it is an important contribution to the ongoing discussion of groundwater banking. Whatever your position in the California Water Community, it is in this context that we thank you. Only an open exchange of ideas will transform groundwater banking into a water management reality and we look forward to continued dialogue in the months and years to come.

Preface

Periodically since 1957, the California Department of Water Resources has published *The California Water Plan*. A review of these documents reveals that what began as an inventory of existing water supply and demand patterns, and projected future changes, has evolved into planning document which recommends options for balancing water demand and supply in the future. Bulletin 160-93, the 1993 version of *The California Water Plan Update*, was particularly noteworthy in terms of its recognition of the need to integrated the management of the state's surface water and groundwater resources (conjunctive use). According to *The Plan* (DWR 1994):

> In the future, carefully planned conjunctive use will increase and become more comprehensive because of the need for more water and the generally higher cost of new surface water facilities. Conjunctive use programs generally promise to be less costly than new traditional surface water projects because they increase the efficiency of water supply systems and cause fewer negative environmental impacts than new surface water reservoirs (page 103).

This statement is full of promise and expectation, positive tones which have sustained a conceptual discourse on conjunctive use and groundwater banking in California for many years. The end result of this promise and expectation is that groundwater banking has become an element of the standard litany of water management strategies for California, and is often held up as a win-win alternative for the state's disparate stakeholders.

When an attempt is made, however, to translate the conceptual model into actual yield enhancing projects, promise and expectation often give way to concern and uncertainty. Focusing attention on the conjunctive management of specific rivers and groundwater basins consistently raises "red flags" for those whose livelihoods depend on these resources. NHI does not seek to discredit these reactions. Given the level of investment in the current water management system and the hydrologic and economic uncertainly associated with conjunctive use, most are legitimate. Nonetheless, this report adopts the perspective that these concerns should catalyze analysis and dialogue, not extinguish them. The research we have conducted to date flows from this perspective and responds to many of the regularly waved red flags. In the interest of catalyzing increasingly site-specific analysis, the pages of this document report that:

- Re-operation of the terminal reservoirs on each of the major rivers between the Lake Shasta and Millerton Lake as part of a maximal groundwater banking program, in coordination with reservoirs located upstream, could generate approximately 1 MAF of average annual yield and increase the overall performance of the surface water infrastructure.
- Under existing law, there is no proscription against importing surface water for storage in a groundwater basin and eventual recovery for use off site.
- An inventory of potential aquifer storage sites discovered over 10 MAF of available storage a various places around the Central Valley, much of which could be accessed by re-operating and/or modifying conveyance infrastructure.
- Modification of conveyance infrastructure in a portion of the Sacramento Valley could enhance the yield of Shasta Dam by up to 40 TAF during dry years, while assisting water managers in Yolo County forestall future groundwater overdrafts.
- By increasing yield on the San Joaquin River, aquifer storage at Gravelly Ford could allow for downstream releases of approximately 144 TAF to restore the anadramous fishery while largely preserving the important agricultural economy in the southern San Joaquin Valley which currently diverts nearly the entire flow of the river.
- The proximity of a significant aquifer storage resource to the east of the Delta in San Joaquin County could increase the reliability of water supply south of the Delta, relieve chronic groundwater overdraft conditions and allow for enhanced Delta outflow when integrated with enhanced Delta conveyance infrastructure.
- At a cost which is generally less than $300 per acre-foot, groundwater banking projects similar to the examples cited above are must more affordable that surface water development projects which can cost up to $3000 per acre-foot.

These findings are an exciting step in the translation of a conceptual model of groundwater banking into actual programs which produce new water for both water supply and environmental restoration. We are optimistic that they are sufficiently compelling to allow some red flags to be lowered, if not furled. In keeping with this optimism, NHI anticipates that the analysis presented in this report will launch a useful dialogue about fulfilling the promise of groundwater banking. This analysis employs several innovative analytical tools which we expect will assist in developing a consensus around this management strategy. These including:

- The Conjunctive Use Potential model, or CUP, which can be used to assess the yield potential of the Central Valley reservoirs under a variety of assumptions regarding reservoir operating rules, conveyance capacities, and aquifer storage space.
- A legal matrix which weighs the relative strength of claims to various types of water stored in groundwater banking sites.
- A matrix of criteria which can be used to rank the suitability of specific groundwater banking sites.
- The Water Evaluation and Planning system, or WEAP, a monthly time-step water allocation model which allows for operational simulations which place specific groundwater banking sites in the context of surface water infrastructure and distributed water demand.
- An extensive database of existing groundwater banking activity in California which can be mined for important insights about avoiding potential pitfalls in the path towards groundwater banking.

We recognize that the task of fulfilling the promise of actual groundwater banking opportunities will only come from site-specific analysis which sufficiently resolves local details to allay the concerns of local actors and regional water managers alike. Our next phase of analysis will involve extending preliminary operational analysis similar to that conducted in Yolo and San Joaquin Counties and along the San Joaquin River to the other potential sites depicted on the cover of this report (also Figure 8). In all cases further refinement of site specific analysis will include:

- Facilitating stakeholder consultations;
- Defining operational changes required to practice groundwater banking;
- Assessing the suitability of groundwater banking in light of competing land uses;
- Evaluating potential environmental complications;
- Addressing local socio-economic and political realities;
- Optimizing the economic value of the site; and
- Resolving legal and institutional barriers.

The end result of this effort will be a suite of the most compelling groundwater banking opportunities ready for presentation to policy makers. The importance of this step cannot be underestimated. The policy making community must have this analysis in hand before making any final decisions about groundwater banking. Absent a well articulated strategy for capitalizing on this storage modality, it is unlikely that any storage enhancement program can be advanced. NHI offers ours analysis as an important contribution to this articulation.

I. Introduction

California's Central Valley watershed, made up of the San Francisco Bay-Delta Estuary and its upstream tributaries, is an extraordinary environmental resource for fish and wildlife. At the same time, the watershed provides much of the water that fuels California's enormous economy. Experience gained during the 1987-1992 drought indicates that operating the installed hydraulic infrastructure in the Central Valley under existing rules and proposed regulations will increasing bring economic and environmental water management objectives into conflict. The hard reality is that under rigid adherence to antiquated management arrangements, the Central Valley watershed cannot shoulder the enormous burden of simultaneously satisfying environmental and economic needs. Both the economy and the environment will ultimately suffer if this incompatibility remains unresolved.

One path towards resolution is increased water use efficiency and demand management. Environmentally benign water development which capitalizes on the storage capacity available in California’s chronically dewatered aquifers is another. While in no way discounting the potential benefit of the first approach, this paper reports the findings of a feasibility study which rigorously explored the second path, specifically the potential for increasing both environmental and economic water supplies through an aggressive, maximal scale program of groundwater banking in the Central Valley water system. The results are very promising. Based on hydrologic considerations alone groundwater banking has the potential to provide approximately 1 MAF of additional annual yield, with the greatest benefit coming in new opportunities to supply consumptive demands and to enhance stream flows.

NHI's specific mission is to seek out and define opportunities for the conservation of natural resources. In responding to this objective, we cannot ignore the environmental benefit which an annual 1 MAF augmentation of water supplies in California would create. Cognizant of the pressing need to rededicate water back to the rivers and estuaries whence it has been diverted over the past century and a half, we have viewed this potential yield increase largely through the optic of environmental restoration. NHI, however, is also very pragmatic. Recognizing that powerful interests will naturally seek to defend the economic developments made possible through historic water diversion, ***we sought to demonstrate that groundwater banking can become one of the elusive win-win alternatives long desired by the California water community***. To make this case we adopted a very systematic approach towards analyzing and surmounting the physical, legal and institutional barriers which could stymie full realization of the yield potential associated with groundwater banking. The intent of this reductionist approach is to preemptively respond to the visceral reactions which are sure to greet a call to strengthen the ties between the management of California’s surface water and groundwater resources. By addressing, and hopefully dispelling, some of these concerns in advance, this report lays the groundwork for to the full realization of the wide-spread benefit made possible through groundwater banking.

Funding from the Ford Foundation enabled NHI to produce this feasibility study. Although the work is the most comprehensive collection of analysis on the various aspects of groundwater banking in California produced to date, much work remains if we are to witness on the ground changes which capture the potential benefits of 1 MAF of new annual yield. NHI will use this feasibility study as a vehicle to actively solicit supplemental support from foundations, as well as from interested agencies and private sector beneficiaries, so that implementation of groundwater banking can help reduce the burden on the Central Valley water system.

I.1 The Problem: Imbalance Between Existing Stocks and Anticipated Flows

In the parlance of systems analysis, system reliability is a function of stock and flow characteristics. Systems where the desired flows are a large fraction of available stocks are vulnerable to disruption. This general axiom is true whether the system in question is a warehouse which furnishes goods in satisfaction of retail demand or a system of reservoirs which furnish water to cities and farms. Just as the warehouse which barely keeps up with retail demand in June will not satisfy the December rush, so a system of reservoirs which just covers demand under average hydrologic conditions will have difficulty providing adequate water supplies during times of drought. Municipal supply organizations have long understood the importance of system reliability. A survey conducted for the California Urban Water Agencies estimated the statewide value of water supply reliability to urban consumers at more than one billion dollars annually (Barakat & Chamberlin 1994). The Metropolitan Water District of Southern California began its recent Integrated Resource Planning process with the establishment of water supply reliability goals (MWD 1995). Only having set these goals did MWD begin to evaluate the anticipated levels of water supply and demand.

In California, the anticipation is that municipal demand will increase in response to population growth. The important agricultural industry in California would like to preserve historic production levels while at the same time emerging environmental standards respond to the critical need for additional water to enhance stream flow, particularly during dry years. Once again in the parlance of systems analysis, the desired flows in the California water system are likely to increase. Historically, the response to increased demand has been to increase stocks by constructing massive surface reservoirs. This approach, however, has fallen out of favor due to its high economic and environmental costs and it is unlikely to prove useful in the future without exhaustive consideration of alternatives. However, when the existing stocks fail to capture the excess wet year supplies needed to satisfy higher anticipated system flows, both economic and environmental values will be threatened. To reduce future disruptions, the desired system flows should be regulated via demand management. In addition, however, opportunities for increasing stocks, to the mutual benefit of economic and environmental interests, should be explored. This report focuses on one particularly compelling strategy for enlarging the stock, groundwater banking.

I.2 A Solution: Groundwater Banking to Increase Future Stocks

Relative to the construction of surface water reservoirs, enlarging the stock via groundwater banking, the storage of excess wet year supplies in subsurface aquifers, is a less controversial, lower cost, more environmental benign approach. Groundwater banking has numerous economic and environmental advantages compared to surface water storage: it reduces losses from evaporation, thus allowing for long-term storage; it allows for greater regulation of natural inflows, without the construction of a huge new network of reservoirs;[1] and it is generally less expensive than surface storage. As with all water storage systems, however, the main purpose of groundwater banking is to convert a fluctuating input of water from precipitation and snowmelt, into a steady supply stream which responds to a water demand pattern which differs from the input stream. Also in keeping with other forms of storage, groundwater banking occurs when water is plentiful, and produces stocks to tap when water is scarce.

Based on this operational definition, the natural hydrologic system is the preeminent practitioner of groundwater banking. During wet years, excess precipitation and elevated stream flows result in high levels of infiltration. As a result, aquifer recharge exceeds pumping, which has been suppressed by well endowed surface water supplies, and there is a net inflow into the aquifer. Groundwater has been banked. When dry hydrologic conditions return, suppressing both infiltration and surface water supplies, pumping by those overlying the aquifer will exceed recharge and the bank will be tapped. Natural groundwater banking, which cycles volumes of water which are orders of magnitude larger than those contemplated here, is not the focus of the maximal program of groundwater banking. Nor will the program rely on shaving the peaks off of the relatively infrequent and limited duration large flow events which already occur below California’s surface water reservoirs during wet years.

In order to increase the available stock, the maximal program of groundwater banking will start by intentionally transferring water from surface water storage to a groundwater bank during the late spring and summer. As this is the period of time when storage in California’s reservoirs is generally highest, the transfers can be aggressive and sustained. They can be accomplished either directly, through percolation at spreading basins, or through "in lieu" surface water deliveries in areas which rely heavily on groundwater pumping . The result of several months of intentional transfer will be an increment of additional storage in an aquifer and the equal increment of potential storage space in the surface water reservoir. Final

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[1] New facilities would be required but the unacceptable environmental and economic costs associated with primary dependence on surface storage could be reduced.

augmentation of the available stock in the system will be accomplished during subsequent winter storms and early spring runoff when the extra available reservoir space enable flood control operations which capture an increased volume of the reservoir inflow. Should a reservoir emerge from the wet season full, then the increment of water in the groundwater bank represents yield which would have otherwise gone unrealized. With these additional supplies in place, when the next dry year inevitably comes, economic demand for water may be satisfied from the groundwater bank, leaving the available surface water to be used to respond to the critical environmental need for enhanced stream flow.

1.3 Building a Case

This type of groundwater banking, which can help satisfy both economic and environmental water supply needs, has not developed on a significant scale in the Central Valley. The workplan which was implemented in carrying out this feasibility study was conceived to systematically address the barriers which have prevented aggressive groundwater banking from occurring. First among these is the perception that surface water reservoirs must be operated to serve only a narrow set of project beneficiaries. This parochial attitude towards the State's hydraulic infrastructure has discouraged the type of hydrologic analysis needed to determine the full water supply potential of a maximal program of groundwater banking. In a similar manner, the dependence of anadramous fish in the Central Valley on cold water releases from the major foothill reservoirs has forestalled consideration of aggressive reservoir re-operation.

Workplan Step 1: Hydrologic Potential Analysis
Assuming perfectly efficient storage and recovery potential, investigate the magnitude, frequency, and location of water that, absent reservoir re-operation as part of a maximal program of groundwater banking, would be released for flood control purposes and would otherwise be unavailable for environmental or consumptive purposes. Constrain the analysis only by the need to maintain suitable temperatures for fisheries downstream of the major foothill reservoirs.

The fear that this re-operation could further imperil Central Valley fisheries is not without merit. In one case where intentional transfers of surface water to aquifer storage have been accomplished, the environmental effects have been extreme. Because of the relatively small size of its central reservoir, the beneficiaries of the Friant-Kern unit of the Central Valley Project aggressively maximize pre-delivery from Millerton Reservoir on the San Joaquin River to the aquifers below their service area, to the point that a stretch of the San Joaquin below Friant Dam is frequently dry. The Friant-Kern example illustrates both of the potential for groundwater banking to enhance stocks, and the risk posed when the sole beneficiaries of the enhance groundwater storage are the local consumptive uses. This scenario is possible because water in groundwater storage in the Central Valley is viewed differently than surface storage. Whereas surface storage is endowed with specific user rights, even for distant beneficiaries, groundwater it is generally perceived of as a local resource, available only to overlying landowners. As a result, the use of groundwater storage to provide economic and environmental benefits for areas remote from the aquifer storage site is relatively rare in the Central Valley.

Workplan Step 2: Legal and Institutional Analysis
Investigate the legal support for the perception that the benefit of all water stored in a aquifer is the sole possession of overlying land owners and describe institutional arrangements, including voluntary contractual arrangements, that would be necessary to get overlying landowners and water districts to cooperate in a program of groundwater banking with broad economic and environmental benefit.

And yet, in the San Joaquin Valley the potential for maximal groundwater banking is massive. Past dependence on groundwater has produced areas where the water table is depressed, creating opportunities for storage. Moreover, heavy groundwater development has catalyzed a number of detailed hydrogeologic studies and information on aquifer characteristics is widely available. In the Sacramento Valley there are fewer areas of long term overdraft as there exists a high degree of interaction between rivers and groundwater. Thus, groundwater elevations tend to recover relatively quickly during wet period following dry years when heavy pumping occurs. While this natural interaction between river and groundwater is useful for local water users, it complicates

Workplan Step 3: Site Analysis
Identify groundwater basins which are well suited for direct recharge and retrieval and/or in lieu recharge and retrieval based on the physical characteristics of groundwater basin as well as land use patterns, ownership, water district jurisdiction and water supply systems. Display sites on a map.

efforts to use Sacramento Valley aquifers as a storage medium for non-local beneficiaries. While areas do exist within the Sacramento Valley where groundwater levels have been permanently depressed by pumping, there is less local incentive to pursue intentional groundwater storage north of the Delta. As a result the hydrogeology of the Sacramento basin remains poorly documented and accounting for the water stored can be a significant problem. In both the Sacramento and San Joaquin Valleys, however, detailed inventories of potential groundwater banking sites need to be elaborated and presented. Of particular interest should be the degree to which integration of a particular groundwater basin into the Central Valley water system facilitates the efforts of overlying water managers as compared with strictly local water management initiatives.

Even with this inventory in hand, however, developing an operational strategy to capitalized on specific groundwater banking opportunities will remain problematic. Surplus surface water for groundwater banking is most commonly available in the Sacramento Valley. The Mokelumne River, and the San Joaquin tributaries, while endowed with excess surface waters, have less substantial hydrologic potential. Hydrogeologically, however, many of the most promising storage sites lie in the San Joaquin Valley. Moving excess Sacramento Valley surface water to these sites may involve transit through the Delta, from which exports are increasingly constrained. Overcoming this potential barrier will turn upon the ability to investigate the operational details of linking reservoir operations to groundwater storage and recovery. This type of investigation requires a simulation tool which is both flexible and robust so that the scope of potential operating regimes can be defined.

Workplan Step 4: <u>Operational Analysis</u>
Investigate if changes in the current operating regime in the Central Valley can overcome constraints on moving water from re-operated reservoirs to groundwater banking sites, and from there to points of economic and environmental use. These changes may be both physical (e.g., the capacity and availability of conveyance facilities) and regulatory (e.g., Delta pumping standards) in nature.

In addition to operational considerations, economic obstacles to the realization of a maximal program of groundwater banking must be identified and overcome. As both the physical and institutional arrangements for aquifer storage differ from surface storage, so to must the financial considerations. In terms of planning and construction costs, aquifer storage and recovery is significantly less expensive then dam construction. However, some of the ancillary benefits of surface storage, such as hydroelectric power generation, flood control and recreation, which have been used to offset these costs are not associated with groundwater banking. In fact, reservoir re-operation as part of the program may either enhance or detract from these uses of California's reservoirs. In order to build a case for the program, these issues must be studied.

Workplan Step 5: <u>Economic Analysis</u>
Investigate the costs of groundwater banking programs relative to surface water development and define the potential benefits. Comment on unique economic aspects of capturing the available surface water supply, conveyance to a groundwater banking site, and storage and recovery for a prescribed end-use.

NHI began this groundwater banking feasibility study with the hypothesis that: (1) It is physically possible to generate substantial amounts of new water for the environment and the economy using groundwater storage; (2) The environmental and economic benefits of such a program outweigh the costs; and (3) any institutional barriers to the use of groundwater for this purpose can be overcome. By implementing of the five broad programmatic workplan steps described above, NHI sought to test whether this hypothesis is true and under what conditions. NHI recognizes that local concerns over the possible local impacts of groundwater banking **<u>must be</u>** overcome before a maximal scale program can become a reality. Prior to engaging in the difficult negotiations needed to address local concerns, however, some sense of the ultimate payoff is needed. By describing the outcome of the five program steps, this report provides that sense. It is intended to be eminently practical, not theoretical in its approach; it is not an academic exercise, but is intended to lead to action. Our premise is that this convincing portrayal of the potential of a maximal program of groundwater banking will generate an action plan which is useful to the governmental entities and stakeholder groups empowered to craft and implement such an ambitious, yet promising program.

II. The Context

Prior to presenting the conclusions of the five workplan steps, a description of the physical setting for a maximal program of groundwater banking is required. The following sections provide a context and a rationale for elaborating the link between the management of California's installed surface water hydraulic infrastructure and potential groundwater banking sites.

II.1 Surface Water Supply

On average, California is not short of water. Annual runoff averages roughly 71 MAF (78 MAF when out of state supplies are included). In 1990, a relatively dry year, environmental uses such as instream flow standards and wild and scenic river designations accounted for 24 MAF, irrigated agriculture for 24 MAF, urban use for 6 MAF, and "other uses" for 1 MAF. Roughly 30 MAF of the 1990 total was accounted for as "other outflow" -- e.g. not allocated to any specific use (DWR 1994).[2] These long-term averages, however, mask the variability which characterizes California hydrology. Consider that:

- Extended droughts are common. Over the six year periods from 1929-34 and 1987-92, cumulative runoff in the Sacramento and San Joaquin Rivers was slightly above half the long-term average. Runoff in 1976-77 was only 33% of the long-term average for the two rivers.
- Much year to year variability exists. In the period between 1906 and 1993, 27 years were dry to critical while 34 were wet.
- Runoff in California is highly seasonal. Much of the flow occurs during a few months when snow melt and rainfall coincide.
- Surface water supplies are spatially non-uniform. Roughly 75% of the natural runoff is north of Sacramento while 75% of the demand is south (DWR 1994).

The existing storage and conveyance infrastructure is designed to "even out" this variability in surface water supply. However, given the location and intensity of current and anticipated water demand, DWR projects a supply shortfall of between 2.1 and 5.2 MAF by the year 2020 if the capacity of the system remains static.[3]

II.2 Groundwater Supplies

Under current working assumptions one method of covering the anticipated shortfall will be an increased reliance on groundwater. Already, during dry years such as 1990, increased pumping results in a statewide groundwater overdraft of roughly 1.3 MAF. Future increases in demand would suggest that these overdrafts will continue at high levels indefinitely unless major changes in water management occur, particularly in the San Joaquin Valley (DWR 1994). Plans to cope with these changes must be tempered by hydrogeologic realities.

Table 1: Estimated Central Valley Groundwater Storage

Aquifer	Estimated Storage (MAF)
Sacramento Valley	170
Delta	130
San Joaquin Valley	160
Tulare Basin	370
Total Central Valley	830

Structurally, the deposits which form the aquifer system in the Central Valley range from a few tens to a few thousands of feet in depth. Total estimated fresh water within the upper 1,000 feet of these sediments is 830 MAF (Table 2). Traditionally the Sacramento Valley has been thought to consist of

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[2] It is important to recognize that this "other outflow" probably generates environmental benefits and should not be viewed entirely as surplus. The outflow is simply excess to minimum environmental flow standards that have been established for various streams and wetlands

[3] In reality, such shortages would not occur. Rather, water demand would be brought into balance with supply by some means -- water conservation, water recycling, water transfers, or desalinization. However, the economic and social costs and the political consequences of such a large reduction in demand make it highly likely that other means would be found to meet demands, such as additional diversions from the environment. The point of groundwater banking is to find ways to meet growing economic and environmental needs in ways that are acceptable to each side.

a single unconfined aquifer while the San Joaquin Valley was conceived of as an upper unconfined system and a lower confined system below the dense Corcoran Clay member of the Tulare formation. More recent studies conclude, however, that the Central Valley ground water reservoir is more accurately portrayed as a single heterogeneous aquifer, characterized by water bearing sediments interspersed with clay lenses.

Largely according to the nature of local interactions between surface water and groundwater, this vast water bearing reservoir has been divided into four hydrographic subregions: Sacramento Valley, Delta, San Joaquin Valley, and Tulare Basin. In each of the sub-region, all significant streams emerge from the Sierra Nevada or Cascade Mountains to the east. The sole exception is the Sacramento Valley where Stony Creek, Cache Creek, and Putah Creek flow into the valley from the Coast Range Mountains to the west. The mean annual runoff into the Central Valley from the surrounding mountains is about 32 million acre feet. Under historic conditions, the Central Valley rivers recharged the aquifers below the valley floor during periods of high flow and the groundwater sustained the low flow stage in rivers. By comparison, recharge via direct precipitation on the valley floor was a relatively minor component of the historic water balance (± 1.5 MAF/year according to Williamson et al 1989).

The regulation of high flows in the rivers of the Central Valley, combined with extensive groundwater pumping, substantially altered this annual cycle. In many parts of the Central Valley, groundwater no longer contributes to low stage stream flow, which is now comprised primarily of agricultural return flows. Across the region, current groundwater flow patterns are linked to the confounding alterations of the natural system which have accompanied decades of groundwater extraction and the hydraulic manipulation of surface water. In the western San Joaquin Valley, for example, the arrival of imported surface water from the Sacramento Valley raised the water table by as much as 170 feet. Further south in the Tulare Basin, where groundwater remains the primary source of irrigation water, the free surface has fallen as much as 400 feet. In the Sacramento Valley, where the interaction between rivers and the underlying aquifer remains closer to the natural regime, groundwater levels are generally stable. Even this general observation is violated, however, in the rapidly urbanizing regions around Sacramento and in numerous locations along the relatively dry west side of the valley.

The overall impression one gains is that the condition of the Central Valley aquifer has evolved through time and is at present extremely variable across the landscape. Williamson and other (1989) documented the steps leading to this dynamic situation:

- The total flow through the aquifer system increased from about 2 million acre-ft/yr prior to hydraulic development to nearly 12 million acre-ft/yr at the current time.
- Increased groundwater pumping prior to the 1960's, to nearly 11.5 million acre-ft/yr, drove the increase in groundwater flow.
- The groundwater pumping prior to the 1960's depleted total groundwater storage by some 20 MAF and was accompanied by increased pumping costs and dramatic land subsidence.
- Increased importation of surface water to some areas of the Central Valley, beginning in the 1960’s, prompted local declines in groundwater pumping.
- During the early 1980's, groundwater pumping decreased to a level approximately equal to the estimated rate of aquifer recharge.
- Since the arrival of surface water, groundwater levels have risen in most areas benefiting from imported surface water, and elsewhere further decreases in ground-water storage have been arrested.
- From a valley-wide perspective the system has achieve a state of quasi equilibrium where persistent zones of dewatered aquifer are largely in balance with adjacent zones of net aquifer recharge from overlying streams and imported surface water. In this context, any additional increment of groundwater pumping will eventually reduce surface flows.

This is not a system which can sustain the practice of satisfying increases in demand in the coming decades with a steadily increasing reliance on groundwater pumping. Such a strategy would likely return the system to the period of rapidly falling water tables, increased pumping cost, and land subsidence which plagued the first epoch of groundwater dis-equilibrium. There must be some consideration given to the need to increase storage in order to avoid a potentially destabilizing increase in groundwater pumping.

II.3 Storage Opportunities

Table 2: New/Enlarged Surface Storage

New Facilities	Storage (MAF)	Cost ($/acre-ft)
Cottonwood	1.6	480
Auburn	2.3	420
Marysville	1.05	1240
Los Banos Grande	1.73	660
Facility Enlargement		
Shasta	14.3	430
Folsom	1.34	1080
Friant	1.4	2920
Pardee	0.36	1640
Farmington	0.16	300
Berryessa	13.0	610
Total	30.56	

The ability to store additional water and further "even out" natural variability would ease the predicted water availability shortfalls. Although California has a network of some 1400 major reservoirs, total storage in these reservoirs is approximately 42 MAF – only 60% of the average annual runoff (DWR 1994). The creation of sufficient additional surface storage to substantially even out variability is unrealistic. For example, proposals to build Auburn dam, a facility capable of storing 2.3 MAF, have been so controversial that funding has been blocked since Congress initially authorized the project in 1965. Even if Auburn dam were constructed, it would only increase the total system storage from 60 to 62.5% of annual runoff. Construction of all the new proposed surface storage facilities identified in Table 2 would increase the total capture of the system to 71% of annual runoff – and at an unacceptably high financial and environmental cost. Enlargement of the existing facilities in Table 2 would increase the system capture to just above the average annual runoff. As with new facilities, however, the financial and environmental costs of facility enlargement would be high.

That underground aquifer storage is the primary supply-side alternative to the construction of new surface water reservoirs is widely recognized. As stated by the Department of Water Resources: "In the future, carefully planned conjunctive use will increase and become more comprehensive because of the need for more water and the generally higher cost of new surface water facilities." (DWR 1994). Groundwater banking was also recognized as one of the least cost sources in a review of yield enhancement opportunities undertaken under the Central Valley Project Improvement Act (USDOI, USBR et al., 1995) with cost estimates ranging from $60/acre-ft to $120/acre-ft of yield at source – greatly below the $300-$2920 unit cost of new surface storage.

This then is the hydrologic context for a maximal program of groundwater banking. Adequate surface water supplies exist in California if they can be further "even out" in space and time. Absent an effort to accomplish this management change, future anticipated growth in the State's water demand will likely lead to an increased reliance on groundwater pumping, disrupting the quasi-equilibrium currently in place and re-initiating problems with rapidly falling water tables and land subsidence. As the will to accept the high financial and environmental costs of additional surface water development has dissipated, the most viable alternative is to capitalize on the existence of regions of aquifer dewatering which developing prior to the 1970's, and which continue to plague overlying landowners. This is a scenario which can produce widespread benefit across the spectrum of water interests and which is the focus of the programmatic analysis which follows.

III. Workplan Step 1: Hydrologic Potential Analysis

A maximal program of groundwater banking seeks to divert surplus surface water to storage in suitable groundwater basins. This diversion would permit immediate storage and eventual recovery of water which would otherwise flow out to sea. The image most frequently conjured up by the aforementioned description is one of massive pumps and diversion canals, installed and ready to capture water during peak winter and spring flow events. Direct diversion during peak flows is depicted in the hypothetical example in Figure 1. In this case when the average daily flow in the Tuolumne River at Modesto exceeds 4000 cfs, 300 cfs of the large flow event is diverted to groundwater banking. Over the course of the 1994 and 1995 water years this approach generates approximately 80 TAF of storage. The important thing to note about this approach is that it involves manipulation of the hydrograph in the lower Tuolumne River while the storage in New Don Pedro Reservoir upstream remains unaltered.

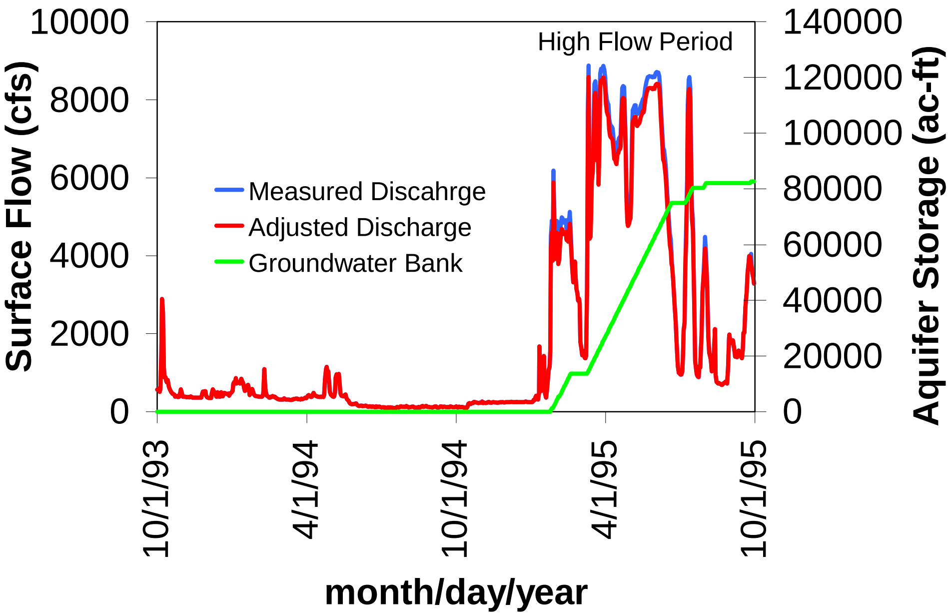

Figure 1: Banking Groundwater by Diverting Peak Flows from the Tuolumne River near Modesto

An alternate, and potentially complementary, strategy for groundwater banking involves the pre-delivery of water from surface water reservoirs to groundwater banking sites. Under this arrangement, water would be released from storage in California's major foothill reservoirs for transfer to aquifer storage during the summer and fall. This transfer could be accomplished directly through percolation at spreading basins or indirectly through *in lieu* deliveries to farms which would otherwise rely on groundwater for irrigation. Instead of directly altering downstream hydrographs during peak flow events, pre-delivery results in a decline in upstream reservoir storage levels. In the hypothetical example in Figure 2, each day between March and September, 1994 a supplemental release of 300 cfs is pre-delivered to groundwater banking from New Don Pedro Reservoir on the Tuolumne River. This re-operation causes a decline in reservoir storage relative to the historic trace which is balanced by a 130 TAF increase in aquifer storage. This aquifer storage becomes "new" water when, during the 1995 water year, measured reservoir releases in excess of 4000 cfs are cutback by 300 cfs. In effect, the excess available flood control capacity in New Don Pedro Reservoir allows for the eventual recovery of surface storage back to the historic trace.

Once storage in New Don Pedro recovers back to historic levels, the water stored in the groundwater bank becomes yield which would have otherwise been released during the peak flow events. It should be pointed out that a 300 cfs pre-delivery is relatively conservative as *in lieu* deliveries to farms could far exceed this level if a suitable distribution network were in place. The subsequent cutback of reservoir releases could also have been more aggressive than assumed in this example. Finally, the re-operation of surface reservoirs is a much more intentional and approach to groundwater banking than the periodic capture of peak flows as it does not require the installation of large diversion capacity which will only be used during short time windows. By "evening-out" the transfer of surface water to aquifer storage, pre-delivery allows for continual benefit to be derived from the physical and operational changes associated with groundwater banking.

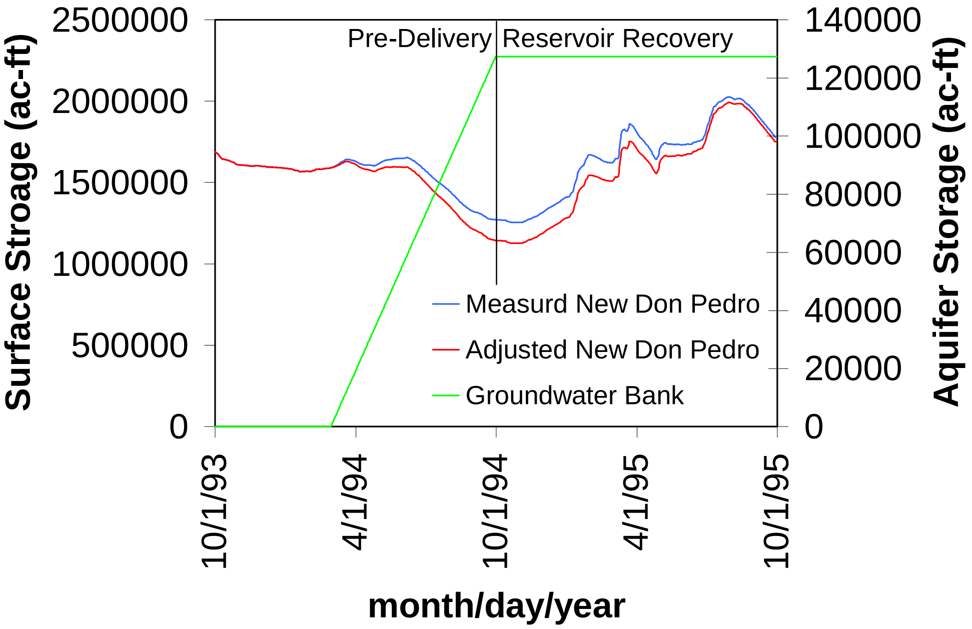

Figure 2: Banking Groundwater by Re-Operating New Don Pedro Reservoir on the Tuolumne River

III.1 Conjunctive Use Potential (CUP)

To estimate the hydrologic potential of the pre-delivery of surface water to groundwater banking in the Central Valley watershed, NHI developed the Conjunctive Use Potential model, or CUP (see the model methodology in the sidebar, parameters in bold italics must be provided by the user). CUP, which was developed for each of the river systems described in Table 3, is based on liberal assumptions about: (1) the existence of infrastructure; (2) a limited scale investment in the direct diversion of high flows to aquifer storage (as in Figure 1); and (3) the availability of suitable groundwater banking sites. On the other hand, CUP adopts a very conservative posture towards the need to preserve adequate cold water in the major foothill reservoirs. This cold water resource is needed to maintain suitable temperatures in the spawning and rearing reaches downstream of the reservoirs in Table 3. The conservative posture should help allay concerns over impacts to hydropower production targets or lake recreation opportunities, although these uses of surface

CUP Model Methodology

1. Compare ***historic daily reservoir releases*** to minimum ***required economic and environmental flows***. Historic releases in excess of required flows are considered "surplus", while smaller historic releases create a "deficit". Accumulate daily differences over the entire year to determine whether the year is wet or dry.
2. When environmental requirements create a deficit, adjust September 30 reservoir storage levels by this increment. Should the adjusted storage falls below a ***minimum carryover storage target*** set to preserve adequate cold water for anadramous fish below the dam, a shortage equal to the amount needed to meet the minimum carryover is applied to economic uses.
3. When a net surplus exists, the adjusted storage from Step 2 is compared to the ***target carryover storage***. If adjusted storage exceeds this parameter, water is pre-delivered to aquifer storage at a rate dictated by user defined ***transfer and storage constraints***. Surface storage is reduced by the same amount. Pre-delivered water is initially "provisional" storage as it can be recalled if needed.
4. Subsequent surplus flows will be held in surface storage until the Step 2 storage trace has been regained, transforming a similar amount of "provisional" storage to banked groundwater. If sufficient surpluses exist to transform all "provisional" storage to banked groundwater, additional surpluses can be transferred into the provisional groundwater account, provided that space is available in the bank.
5. Subsequent deficits which result in adjusted storage below target carryover initiate a search for replacement water and, if necessary, the recall of "provisional" storage at a rate dictated by ***user defined recovery constraints***. A shortage is declared when reservoir storage remains below the minimum target.

reservoirs are not specifically considered in the CUP analysis. The most important lesson to derive from Table 3 is that in six of the ten important rivers in the Central Valley, annual flows exceed the available storage and the improved flood control flexibility made possible through pre-delivery can help capture "new" water without imperiling anadramous fish below the dam.

Table 3: Details of the Major Foothill Reservoirs in the Central Valley

River	Reservoir/Dam	Operator	Storage (TAF)[4]	Mean 1921–1983 Unimpaired Flow[5]
American	Folsom	USBR/CVP	974	2,660
Calaveras	New Hogan	USBR	317	163
Feather	Oroville	DWR/SWP	3,538	4,441
Merced	New Exchequer	MeID	1,025	967
Mokelumne	Camanche	EBMUD	417	730
Sacramento	Shasta	USBR/CVP	4,552	8,303
San Joaquin	Millerton Lake	USBR/CVP	520	1,740
Stanislaus	New Melones	USBR/CVP	2,420	1,131
Tuolumne	New Don Pedro	MoID/TIDD	2,030	1,841
Yuba	New Bullards Bar	YCWA	966	2,333

III.1.1 Protecting Anadramous Fish

Prior to the development of the major foothill reservoirs, listed in Table 3, anadramous fish generally spawned in California's mountain streams. Construction of the dams which impound these reservoirs blocked passage to these sites, forcing fish to spawn in foothill and valley reaches which were historically warm during the summer and early-autumn. Figure 3 compares the water temperature in the Sacramento River downstream of the current Shasta Dam site. Before dam construction the summer water temperature was in excess of 70 °F and remained around 60 °F well into the autumn. Temperature moderation following dam construction resulted from the release of cold water found on the bottom of the reservoir. Similar temperature changes have been observed downstream of the other major Central Valley reservoirs.

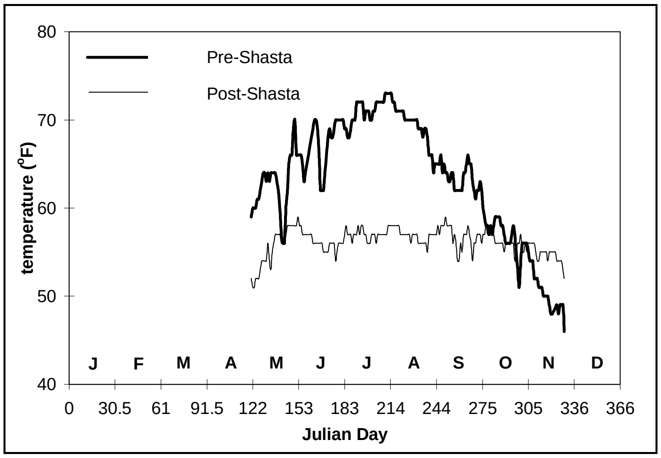

Figure 3: Sacramento River Water Temperature Downstream of Shasta Dam Site
(heavy line: Anderson-Cottonwood Diversion Dam; light line: Balls Ferry)

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[4] Draft of the California Water Plan Update, Department of Water Resources, California Water Commission, November 1993.
[5] California Central Valley Unimpaired Flow Data, 2nd Edition, California Department of Water Resources, Division of Planning, February 1987

The Central Valley Project Improvement Act (CVPIA) enacted in 1992 sought to elevate fish and wildlife protection, and restoration to a level of parity with the other project purposes (U.S. Fish and Wildlife Service 1995). The act also called for a "program which makes all reasonable effort to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991" (CVPIA 1992). For the rivers evaluated using CUP, a variety of temperature related actions were proposed as part of the U.S. Fish and Wildlife Service's Anadramous Fish Recovery Plan (AFRP). Some of these were specific prescriptions, others vague recommendations (see the adjacent sidebar). Table 4 describes specific reservoir carryover targets included in the AFRP.

Relevant USFWS Temperature Prescriptions

In order to maintain water temperatures below 56^{o}F in the **Sacramento River**, Shasta Reservoir should be operated to attain a minimum October 1 carry over storage of 1.9 MAF under all runoff conditions except the driest 10% of water years.

In the **Feather River** pulse releases from Lake Oroville are needed to reduce the temperature difference between the low flow channel and the reach immediately downstream of the Thermalito outlet.

In the **Yuba River**, colder temperatures for chinook salmon could possibly be maintained by drawing Englebright Reservoir down in August and refilling with cold water from New Bullards Bar. Reservoir

In the **American River**, by re-operating the reservoir release shutters to provide greater flexibility, downstream releases during October would be 1-9^{o}F colder than the temperature attained under current protocols and shutter configurations.

In the **Mokelumne River**, a minimum pool in Camanche Reservoir of 190 feet from April through September and a minimum pool of 170 feet from October through March, should be maintained to protect anadramous fish.

In the **Calaveras River**, temperatures could be kept cool enough for chinook salmon production with a minimum New Hogan Reservoir pool size of 85,000 ac-ft.

Water temperature in the **Stanislaus River** should be maintained below 56^{o}F between October 15 and February 15 and below 65^{o}F between April 1 and June 30 in order to enhance salmonid productivity below Goodwin Reservoir.

Water temperature in the **Tuolumne River** should be maintained below 56^{o}F between October 15 and February 15 and below 65^{o}F between April 1 and June 30 in order to enhance salmonid productivity below LaGrange Dam.

In the **Merced River** the same river temperature standards as for the Stanislaus and Tuolumne Rivers are suggested in order to enhance salmonid productivity below the Crocker-Huffman Diversion.

Table 4: AFRP Reservoir Carryover Targets in the Rivers Evaluated Using CUP

River	Specific Carryover Targets	No Clear Carryover Targets
Sacramento	1.9 MAF	
Feather		**X**
Yuba		**X**
American		**X**
Mokelumne	~108 TAF	
Calaveras	85 TAF	
Stanislaus		**X**
Tuolumne		**X**
Merced		**X**

In CUP, constraining the pre-delivery of water from reservoir storage to a groundwater bank based on the need to preserve the cold water pool requires the definition of both minimum and target carryover parameters. These parameters should be defined based on analysis of the physical juxtaposition of warm water in the Central Valley reservoirs with the release works on the face of the impounding dams, and on the thermal requirements of downstream fisheries. The carryover storage levels contained in Table 4 can be used as targets values in CUP. The remaining target parameters and all minimum carryover parameters must be set by the user.

III.1.2 Setting Carryover Targets

The derivation of these carryover parameters rests on physical principles, particularly a solid understanding of the tendency of reservoirs to stratify into warm and cold water pools during the summer and early autumn, and the potential for wind driven oscillation or *seiches* in stratified reservoirs. The limnological basis for this analysis is presented in Appendix I.

III.1.2.1 Required Data

The data required to carry out the required limnological analysis for the major foothill reservoirs in the Central Valley include:

- Historic EOM storage levels;
- Late summer vertical temperature profiles collected when the reservoirs were in a drawn down state;
- Late summer wind speed data from the vicinity of these reservoirs; and
- Information of the physical configuration of each reservoir and the impounding dam's release works.

Table 5 presents a matrix describing the data availability for each of the systems under investigation. In general, data for the Central Valley and State Water Project facilities was more easily acquired than in the case of projects managed by local-agencies. Gaps in the data availability were overcome by substituting the most appropriate data set available.

Table 5: Data Availability Matrix for Analysis of Minimum Carryover Storage Values of the Major Foothill Reservoirs

Reservoir	Operator	EOM Storage	Temperature	Wind Speed	Configuration
Shasta	USBR	✓	✓	✓	✓
Oroville	DWR	✓	✓	✓	✓
New Bullard Bar	YCWA	✓	✓	✓	✓
Folsom	USBR	✓	✓	✓	✓
Camanche	EBMUD	✓	✓	✓	✓
New Hogan	USACE	✓	✓	✓	✓
New Melones	USBR	✓	✓	***Use New Hogan***	✓
Don Pedro	TID	✓	***Use New Melones***	✓	✓
McClure	MID	✓	***Use New Melones***	✓	✓

III.1.2.1.1 Reservoir Storage

Figures 4A (Sacramento Valley) and 4B (San Joaquin Valley) depict the yearly October 1st reservoir storage values, for each of the major foothill reservoirs in Table 3, ranked in ascending order. The five lowest storage values are labeled, excluding the first five years of operation when filling could have influenced the storage levels as much as hydrologic conditions. The severity of the 1976-1977 drought is revealed in the fact that October, 1977 represents the lowest recorded level in eight of the nine reservoirs. The impact of the 1987-1992 drought is also revealed as many of these years also figure among the lowest measured storage levels. By examining the disposition of the cold water resource under these drawn down conditions appropriate carryover parameters can be established.

III.1.2.1.2 Vertical Temperature Profiles

Unlike reservoir storage data, data on the water temperature as a function of depth in the major foothill reservoirs is not collected and reported in a regular fashion. Every attempt was made to acquire temperature data corresponding to the lowest measure reservoir storage (see Figures 4A and 4B). Given the irregular character of this data, however, such a correspondence was not universally achieved. Table 6 summarizes the quality of the vertical temperature profile data collected for this analysis.

Table 6: Availability of Vertical Temperature Data for the Major Foothill Reservoirs Under Drawn Down Conditions

Reservoir	Measurement Date	Storage Rank	% Above Minimum
Shasta	Sept, 1976	3	8.9
Oroville	Sept, 1992	3	8.9
New Bullards Bar	Oct, 1992	>5	112.7
Folsom	Oct, 1977	1	0
Camanche	Oct, 1990	>5	28.0
New Hogan	Aug, 1990	3	1.6
New Melones	Sept, 1992	1	0
Don Pedro	N/A	N/A	N/A
McClure	N/A	N/A	N/A

Figure 4A: Ranked Historic October 1st Storage in the Major Sacramento Valley Foothill Reservoirs with Values of the First Operational Year (bold) and the Five Lowest Years Identified

(A: Shasta; B: Oroville; C: New Bullards Bar; D: Folsom)

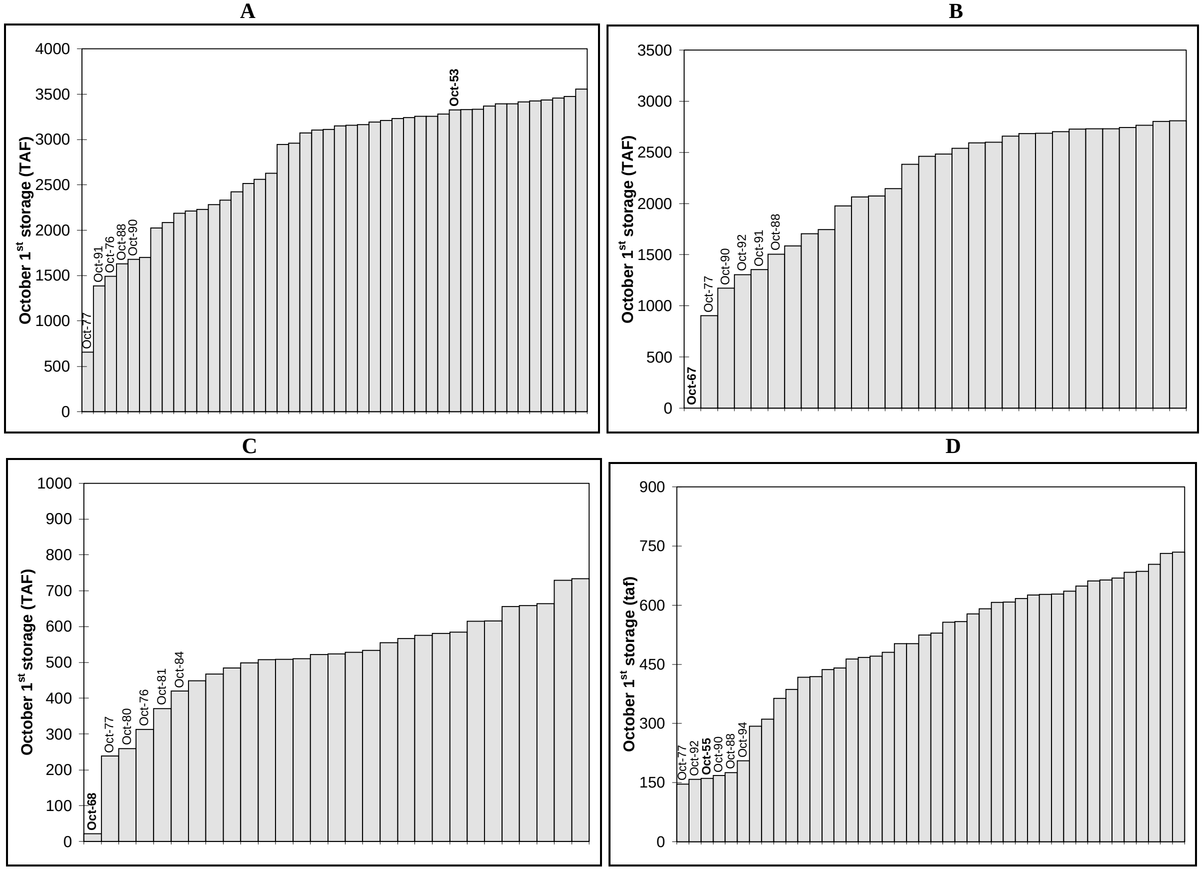
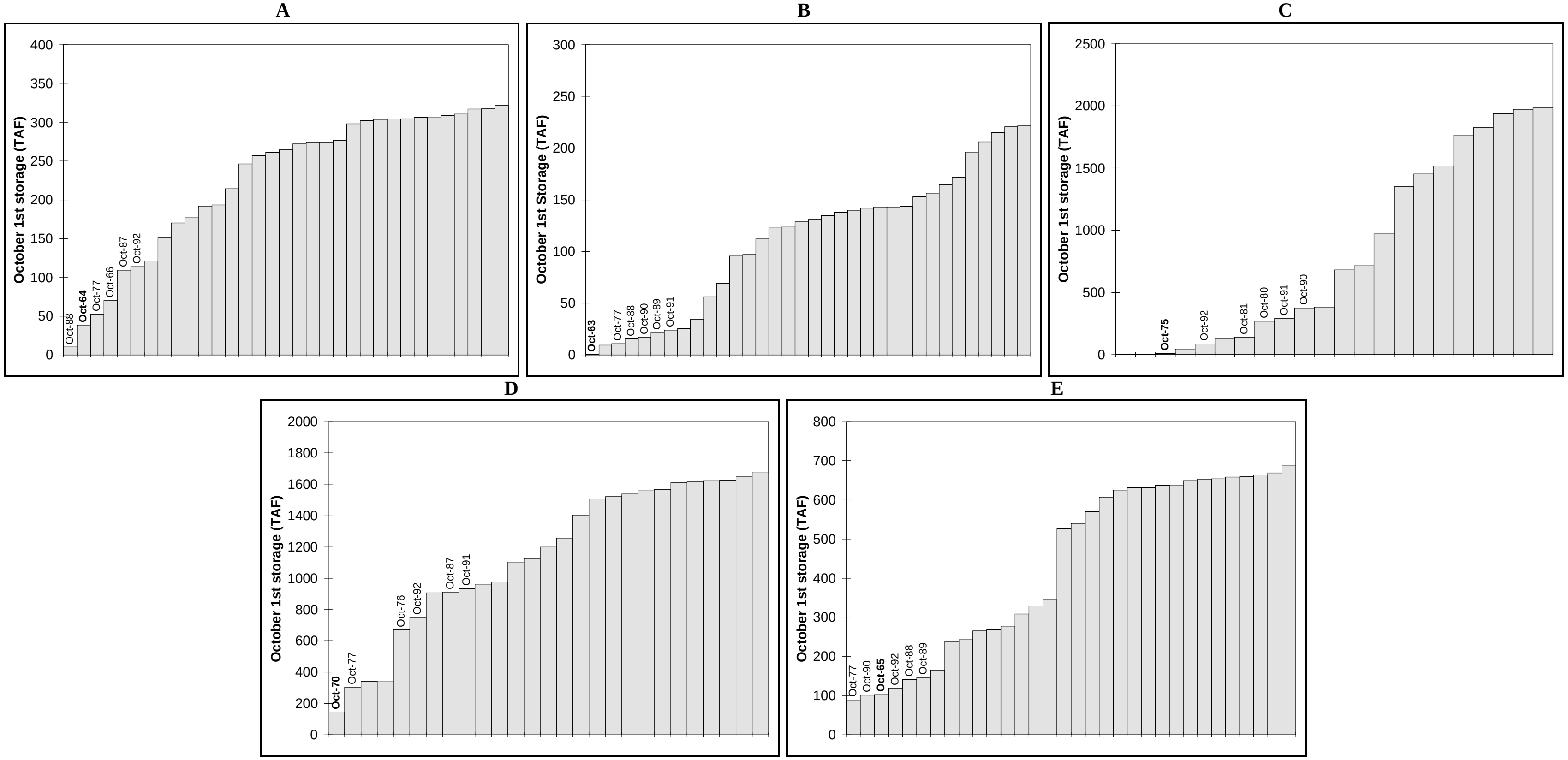


Figure 4B: Ranked Historic October 1st Storage in the Major San Joaquin Valley Foothill Reservoirs with Values for the First Operational Year (bold) and the Five Lowest Years Identified

(A: Camanche; B: New Hogan; C: New Melones; D: Don Pedro; E: McClure/Exchequer)



Using these data to establish acceptable carryover levels relies on the implicit assumption that the interaction between the incoming solar radiation, the prevailing wind, and the volume of the body of water behind the dam remains essentially constant across the range of drawn down conditions. Given the fairly uniform climatic patterns which characterize Central Valley summers, applying this assumption to the two climatic factors seems reasonable. The last column of Table 5 contains the percent increase in reservoir storage at the time of the temperature sounding, relative to the minimum observed October 1st storage reported in Figure 4. With the exception of New Bullards Bar and Camanche Reservoirs, the storage levels at the time of the temperature sounding were not substantially above the minimum observed storage level. Figure 5 contains the vertical temperature profiles plotted as a function of the depth below the lake surface for each of the reservoirs where data was available. The soundings reveal the well developed nature of temperature stratification in these reservoirs during the late summer/early autumn. Any appropriate carryover parameters used in CUP must consider the disposition of the cold water pool in the hypolimnion relative to the physical works controlling downstream releases.

III.1.2.1.3 Wind Speed

The disposition of the cold water resource in the major foothill reservoirs cannot be considered static. Shear stress generated by wind passing over the lake surface performs work on the water body which can disrupt the patterns of thermal stratification observed in Figure 5. In order to assess the potential for disruption, or mixing, the wind speed in the vicinity of the major foothill reservoirs must be characterized. The major foothill reservoirs generally lie somewhere between the elevations of two common wind speed databases containing data collected in the Central Valley (CIMIS) or at higher elevations in the Sierra (CDEC). In order to minimize the potential error associated with the use of this data, the maximum available measured daily average wind speed for each reservoir was used to assess the potential for wind driven mixing. These are shown in bold in Table 7.

Table 7: Wind Speed Measurement Stations Associated with the Major Foothill Reservoirs
(stations with maximum daily average wind speed in bold)

Reservoir	Station	CDEC	CIMIS	Reservoir	Station	CDEC	CIMIS
Shasta	McCloud	✓		Camanche	Beaver	✓	
	Thomes Creek	✓			Mt. Zion	✓	
	Whitmore	✓			**Lodi**		✓
	Gerber		✓	New Hogan	Esparanza	✓	
Oroville	**Butte Meadows**	✓			**Manteca**		✓
	Chester	✓		Don Pedro	**Green Springs**	✓	
	Quincy Road	✓			Tuolumne Meadows	✓	
	Westwood	✓			Modesto		✓
	Durham		✓	McClure	**Crane Flat Lookout**	✓	
New Bullards Bar	Bangor	✓			Mariposa Grove	✓	
	Dorris Ranch	✓			Mariposa Ranger Station	✓	
	Browns Valley		✓		Merced River	✓	
Folsom	**Buffalo Creek**	✓			Modesto		✓
	Camino		✓				
	Linclon	✓					

From the maximum data set, the highest single daily average wind speed was extracted. The assumption implicit in the use of the peak value is that energy imparted to the system by a steady wind blowing for a single day will be sufficient to fully induce wind-driven water movement in the reservoir. The time series of wind speed data from these most windy sites are shown in Figure 6.

Figure 5: Late Summer/Early Autumn Vertical Temperature Profiles for the Major Foothill Reservoirs

(A: Shasta; B: Oroville; C: New Bullards Bar; D: Folsom; E: Camanche; F: New Hogan; G: New Melones)

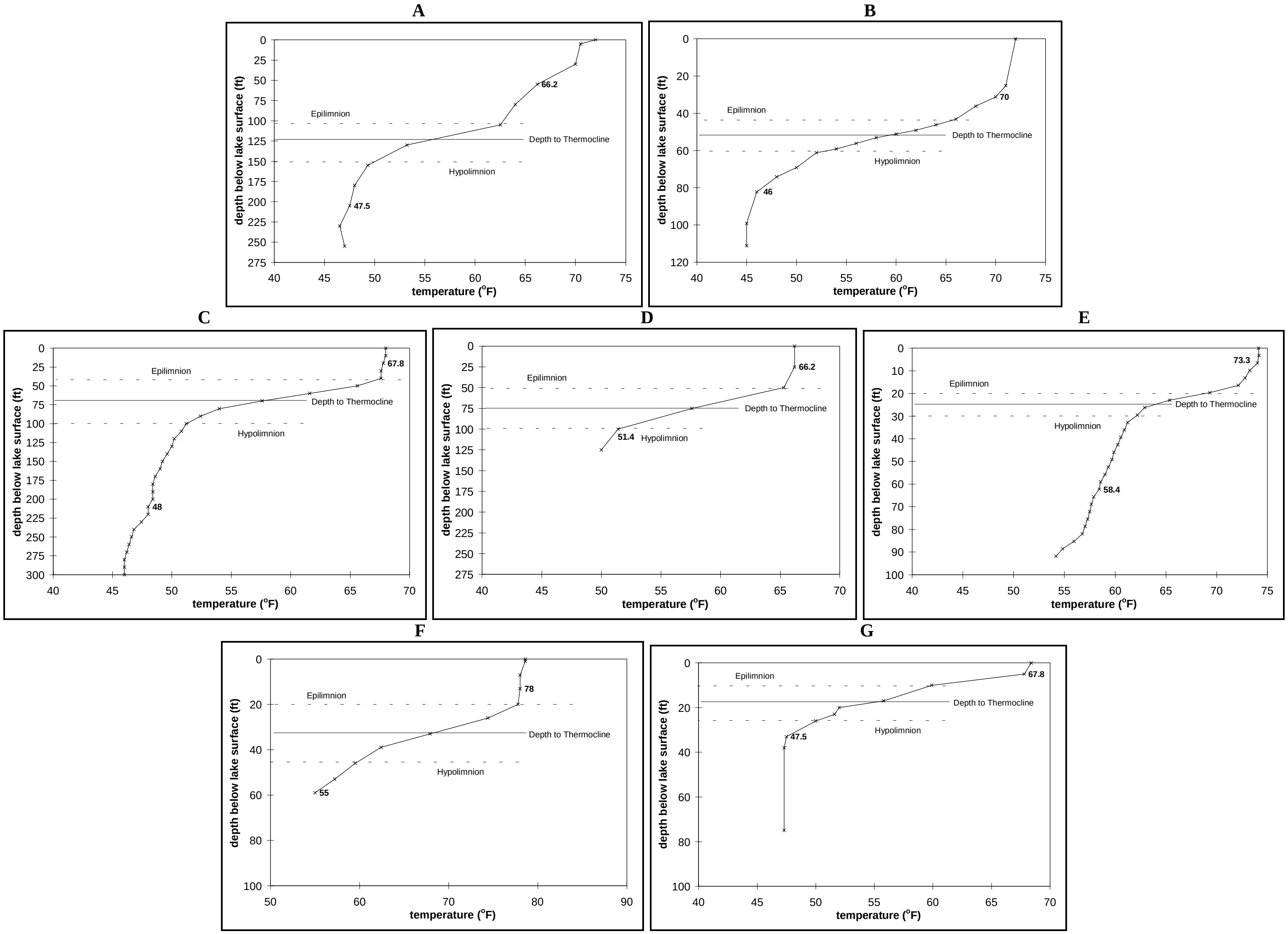
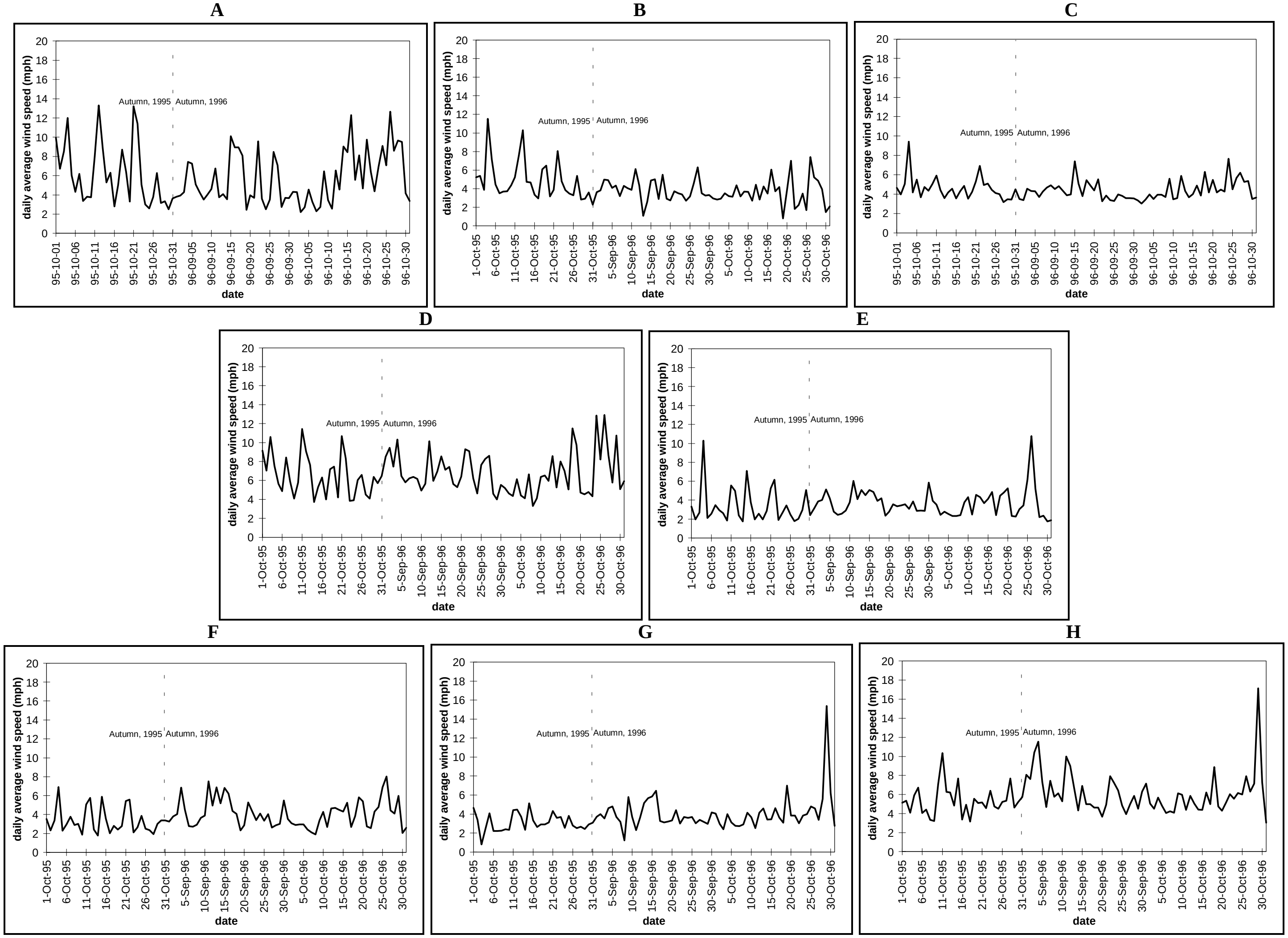


Figure 6: Recent Maximum Late Summer/Early Autumn Daily Average Wind Speed Date for the Major Foothill Reservoirs

(A: Shasta; B: Oroville; C: New Bullards Bar; D: Folsom; E: Camanche; F:New Hogan; G: Don Pedro; H: McClure)



III.1.2.1.4 Physical Configuration

In order to evaluate the disposition of the cold water resource with respect to the release works of a given dam, data describing the physical configuration of the reservoir system is required. This data set includes information on the length of the lake, the elevation of the foot of the dam and the elevation of the release works used to discharge water downstream. Two complications influence the compilation of this data set. First, the major foothill reservoirs are not uniformly long and narrow, which makes it difficult to define the length of the lake corresponding to the fetch of open water above the dam. For this analysis the length was defined as the longest unobstructed distance over water which can be traced at high water from the dam itself. Second, stating the elevation of the release works was complicated by the fact that many of the major foothill reservoirs include installed hydroelectric generating capacity. The elevation from which water is released to the powerhouse is usually higher then the low level release works used for flood control. In order to minimize the potential impact on hydroelectric power production, in this analysis the elevation at which water is released to the powerhouse served as the reference for a comparison with the disposition of the cold water pool. Table 8 summarizes the requiired information for the reservoirs of interest.

Table 8: Physical Configuration Data for the Major Foothill Reservoirs

Reservoir	Length (mi)	Elevation Foot (ft)	Elevation Release (ft)
Shasta	5.9	576	725
Oroville	4.7	180	640
New Bullards Bar	2.3	1400	1622
Folsom	7.8	200	218
Camanche	6.8	100	104
New Hogan	2.0	525	534
New Melones	3.3	500	760
Don Pedro	4.1	290	600
McClure	3.1	400	477

III.1.2.2 Computational Steps

In this analysis, the evaluation of the ability to release cold water downstream from a stratified lake relies upon three sequential calculations carried out for an assumed reservoir storage level and vertical temperature profile. These are

- Determine the set-up of the lake caused by the passage of wind over the lake surface;
- Determine the displacement of the warm water pool, in response to the set-up; and
- Determine the juxtaposition of the warm water relative to the reservoir release works.

Appendix II examines these three computational steps in greater detail, focusing on the physical rationale behind each step.

III.1.2.3 Defining the Minimum and Target Carryover Parameters

Table 4 contains carryover storage targets for Shasta, Camanche, and New Hogan Reservoirs as defined in the Anadramous Fish Recovery Plan (USFWS 1995). These will be used as target carryover parameters in CUP. Appropriate carryover targets for the remaining facilities, as well as the minimum carryover levels for all of the reservoirs, remain unresolved. These values are set according to the following criteria:

$$CS_{target} = \left| \begin{matrix} CS_{AFRP} \\ CS \text{ where } HT \approx 50\text{ft} \end{matrix} \right. \text{ or if none} \tag{1}$$

$$CS_{minimum} = CS \text{ where } HT \approx 20\text{ft} \tag{2}$$

where CS is the carryover storage and HT is the minimum thickness of the cold water pool lying above the release works during wind driven oscillations. In those cases where no carryover standards are available, storage levels were adjusted in a trial and error fashion until conditions yielding HT values of 20 ft and 50 ft were identified. Table 9 presents the final CUP carryover parameter values for each of the nine simulated rivers (The San Joaquin was omitted from this analysis as extensive pre-delivery of surface water already takes place in the Friant Unit). These parameters were not based on political considerations, the sole consideration was the difference between the maximum downward displacement of warm water under *seiche* oscillations and the release works of a given facility. Obviously dams where the power plant intake is located well down the dam face are found to have much lower carryover requirements.

Table 9: CUP Carryover Parameters Developed According to Analysis of the Juxtapostion of Warm Water Relative to Reservoir Release Works (in ac-ft)

River	Carryover Target	Minimum Carryover
Sacramento	1,900,000	910,000
Feather	1,705,00	1,507,000
Yuba	210,000	190,000
American	190,000	100,000
Mokelumne	108,000	70,000
Calaveras	85,000	17,000
Stanislaus	382,000	268,000
Tuolumne	750,000	570,000
Merced	50,000	30,000

III.1.3 Tapping Upstream Storage

In CUP, when the re-operated storage falls below the minimum carryover parameter the model seeks to redress the deficit. The first place where CUP looks for replacement water is upstream towards storage in Sierra Nevada reservoirs. A time series of combined upstream storage for each river has been input into CUP and the user can specify the percentage of the upstream storage which can be tapped to make up any deficit. In CUP, water is returned to the surface reservoir from "provisional" storage only when the available upstream storage is insufficient to fill the gap. Figure 7 presents the time series of available upstream storage volumes.

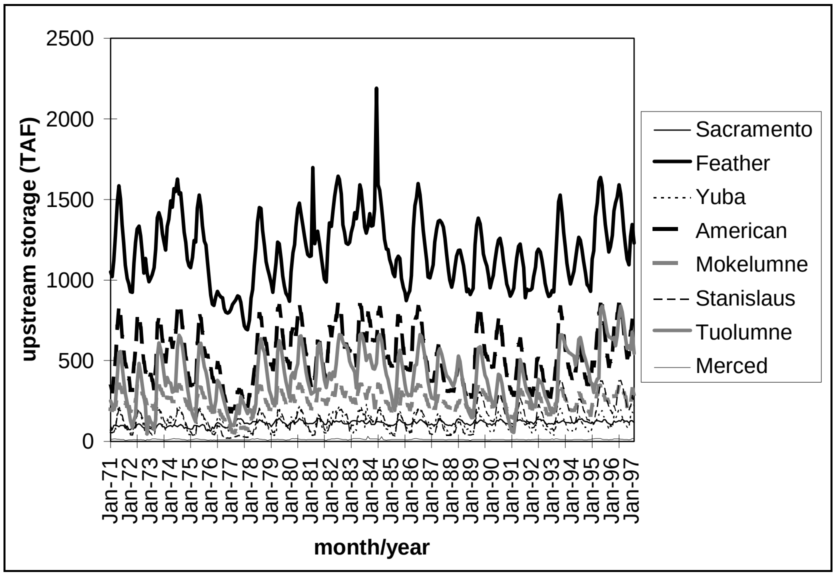


Figure 7: Time Series of Total Storage Upstream of the Major Foothill Reservoirs

III.1.4 CUP Simulations

Four different scenarios were simulated using CUP. These are summarized in the matrix shown in Table 10. The base case represents the case where instream flow standards are set to the highest possible level, carryover standards set in the AFRP are used where available to define the carryover target parameter, and 20% of the upstream storage can be tapped to make up any deficit relative to the minimum carryover. The other three simulations are departures from this base case. Scenarios 2 through 4 are designed to evaluate the sensitivity of the estimated average annual yield to various management strategies. Scenario 2 in particular merits some explanation. In this simulation the AFRP prescribed carryover targets are set aside in favor of the more aggressive targets derived from the application of the equations (1) and (2) to Shasta, New Hogan, and Camanche Reservoirs. Under each of these scenarios, a small simulated capacity to capture flow during peak winter and spring flow events was included (as depicted in Figure 1). It is important to keep in mind, however, that this approach is considered secondary to reservoir re-operation in CUP.

Table 10: Simulation Matrix for Revised CUP Model

Scenario	Carryover Target	Instream Standard	% Upstream Available
1. Base Case	AFRP if available, otherwise HT =50 ft	HIGH	20%
2. Set Aside AFRP	HT =50 ft everywhere	HIGH	20%
3. Relax Standards	AFRP if available, otherwise HT =50 ft	MEDIUM	20%
4. Full Upstream	AFRP if available, otherwise HT =50 ft	HIGH	100%

III.1.5 Results

The estimated average annual yield in the base case simulation is 894.4 TAF, a significant quantity of water which could contribute mightily to the quest for consensus in California's water sector. In addition, the alternative management strategies described in scenarios 2 through 4 improve the performance of the groundwater banking program. Table 11 summarizes the results for each simulated river under each of the management scenarios.

Table 11: Average Annual Yield Estimates from Revised CUP Model (in TAF)
(CU: conjunctive use re-operation; HP: capture of hydrograph peak)

	Base Case			**Set Aside AFRP**			**Relax Standards**			**Full Upstream**		
River	CU	HP	Total	CU	HP	Total	CU	HP	Total	CU	HP	Total
American	64.8	15.6	80.4	64.8	15.6	80.4	72.9	17.4	90.3	137.1	15.2	152.3
Calaveras	12.8	12.6	25.4	15.9	11.5	27.4	14.7	13.2	27.9	12.7	12.6	25.3
Feather	107.3	19.6	126.9	107.3	19.6	126.9	122.8	21.7	144.5	117.1	19.6	136.7
Merced	92.9	15.2	108.1	92.9	15.2	108.1	134.7	22.4	157.1	93.0	15.2	108.2
Mokelumne	53.7	15.7	69.4	51.6	15.7	67.3	77.6	23.3	100.9	59.6	15.0	74.6
Sacramento	170.8	26.0	196.8	184.5	26.0	210.5	195.3	31.2	226.5	170.8	26.0	196.8
Stanislaus	51.6	13.4	65.0	51.6	13.4	65.0	79.5	26.4	105.9	58.3	13.4	71.7
Tuolumne	65.3	12.6	77.9	65.3	12.6	77.9	116.4	24.8	141.2	72.1	12.4	84.5
Yuba	117.5	27.0	144.5	117.5	27.0	144.5	157.8	31.3	189.1	122.6	27.1	149.7
Total			894.4			908.0			1183.4			999.8

Relative to the base case, the most dramatic improvements come from reducing the simulated instream flow standards from high to medium. Even without relaxing the instream flow standards, however, the performance of the system can be improved by taking full advantage of the opportunity to release water from storage in upstream reservoirs when it is needed to re-establish the minimum carryover level on October 1st. Table 12 details the pattern of reliance on upstream storage which emerges from this simulation. Although the use of this water affords extra benefit to the ground water banking program, any advantage gained must certainly be weighed against power generation potential which might be lost in the process. This analysis suggest, however, that the notion of integrating storage upstream of the major foothill reservoirs into the maximal statewide groundwater banking program is certainly worth pursuing. This type of integration, however, would involved a wide array of actors running from the electric utilities which operate the upstream reservoirs, the water agencies which operate the major foothill reservoirs and their customers, and the land owners overlying the potential aquifer storage sites. The complexity of negotiating arrangements acceptable to all these parties will require a keen eye towards the legal and institutional nuances governing groundwater in California. Given the enormous potential payoff, however, there should be ample incentive to address any potential problems.

Table 12: Simulated Transfers from Upstream Storage to the Major Foothill Reservoirs under the Full Upstream Scenario (transfers in ac-ft)

River	No. of Transfers	Average Transfer
American	10	182,649
Calaveras	0	0
Feather	7	182,764
Merced	5	9195
Mokelumne	9	55,427
Sacramento	6	106,904
Stanislaus	3	87,343
Tuolumne	8	131,810
Yuba	3	53,935

IV. Workplan Step 2: Legal and Institutional Analysis

The infusion of approximately 1 MAF of new water into the California water system on an annual basis would undoubtedly help water managers in the state to meet water supply and environmental objectives. Realizing this hydrologic potential, however, requires that legal and institutional barriers be identified and surmounted.

IV.1 Basic Premise

Basically, the incentives for a maximal program of groundwater banking would be as follows, landowners overlying the storage site would agree to store the water as part of the program in exchange for a portion of the “new” water, or for a cash payment. Water will be regarded as “new” water if it would otherwise have been released for flood control purposes and flowed out to sea. Well monitoring may be necessary in selected areas to prevent increased pumping by overlying and adjacent landowners in storage areas, who could be tempted to irrigate new lands, avoid higher surface water costs, and/or to compensate for unrelated market transfers of surface water rights. Opportunities may exist to incorporate storage entities as a part of AB 3030 groundwater management plans for districts throughout the state, indeed in the case of *in lieu* storage this may be the preferred approach. Potential beneficiaries of the groundwater banking program would be invited to participate in the arrangement under agreements that would give them access to purchase a specified amount of the banked groundwater. The funds collected from the beneficiaries would be used to defray the costs of the program, which are expected to include the construction of new infrastructure and electricity for pumping the stored water.

IV.2 Basic Approach

A preliminary analysis of California groundwater law has been conducted to explore how a groundwater banking program could be set up so that the rights to the program water stored in groundwater basins could be protected against claimants which are not participating in the program. In pursuing this legal research two program designs were considered: (1) groundwater banking through active recharge and (2) groundwater banking through *in lieu* arrangements. Both designs would tap flood control releases that otherwise escape beneficial use. Thereafter the program designs diverge somewhat as they are predicated on different legal entitlements to extract and use the stored groundwater. The details of this legal research are included in an August, 1994 NHI document entitled *Analysis of Preferences in Rights to Groundwater Under California Law & Implications for Design of Conjunctive Water Use Programs*.

In this analysis NHI defined a number of distinct “types” of groundwater. While from a hydrologic perspective, a molecule of groundwater in a basin is not physically distinguishable from any other molecule, our analysis suggests that from a strictly legal perspective there are multiple groundwater types in the State. Our conception of a maximal scale groundwater banking program will focus on Groundwater Type 5, where the organizer of a groundwater banking program would seek to obtain rights to groundwater that is *percolating, used off-tract, imported to the watershed of use, and required for reasonable beneficial use, where area of origin statutes are inapplicable*. In more practical terms, this is groundwater which was imported from outside the groundwater basin, which has not become the underflow of a surface stream nor an underground stream, and which will be put to beneficial use at a location physically removed from the land overlying the basin. This type of groundwater offers several important protection to the organizers of a groundwater banking program. The most salient details of the legal analysis on the active and *in lieu* program designs are framed as responses to pertinent questions.

IV.3 Legal and Institution Questions

The questions posed below go right to the heart of perceptions that the benefit of water stored in an aquifer is the sole possession of overlying landowners. The responses assert that for groundwater of Type 5, at least, this perception is not universally valid. Having established this conclusion, questions related to how to best capitalize on potential storage opportunities can be posed.

IV.3.1 Could parties with potential claims on Groundwater Type 5 hamper the eventual recovery of stored groundwater?

IV.3.1.1 In the Case of Active Recharge

The universe of parties with potential claims to Groundwater Type 5 includes: the people of California through the public trust, as well as importers, prescribers and appropriators--both private and public.

The public trust is omnipresent. No disadvantage is incurred by using water of this type, since no type of water escapes the reach of the trust.

Prescribers, overlying users, and other importers are not of concern, if water of this type is used. If the organizer of the groundwater banking program is a public entity, as described below, prescribers are eliminated from competition for water imported by the organizer. The only colorable claim of overlying groundwater users to water of Type 5 would result if the importer abandoned the imported water once it was in the ground. Spreading does not constitute such abandonment.[6] Other importers can claim only rights to a quantity of water attributable to their own imports--a situation that does not threaten the operation of a groundwater banking program. Thus, a public importer of water of this type need only be concerned about being displaced by appropriators.

Appropriators have a superior claim to water of this type only if the importer fails to require the water for reasonable beneficial use--that is, if the water is considered “surplus.” The burden of proof would be on the would-be appropriator to show that such water was, in fact, surplus.[7] Storage of groundwater for domestic, irrigation, and municipal purposes is typically considered a reasonable beneficial use.[8] Storage of groundwater is a beneficial use if the water is later applied to the beneficial purposes for which the water was first appropriated on the surface.[9] Thus, it is important that, in addition to manifesting an intent to recapture imported waters stored in the ground, the organizer of the groundwater banking program demonstrate that such waters are being stored for later application to reasonable beneficial uses. In this way, the storage itself will be considered beneficial.

Thus, if the organizer of the groundwater banking program holds rights to groundwater of Type 5, the program should be able to deposit water in the ground and, by right, withdraw it again.

IV.3.1.2 In the Case of *In Lieu* Arrangements

Under an in lieu system, the program would enter into arrangements with overlying landowners who already have access to groundwater. During periods when the program desires to recharge groundwater, the landowners would forego pumping and accept a substitute surface delivery from the program instead. In the case where the landowner has access to surface water, when the program desires to withdraw groundwater, the landowner would curtail its surface water use and substitute groundwater pumping. When the landowner has no independent claim to surface water, recovery by the program would rely on the physical extraction of stored groundwater.

The basic problem with such an arrangement is that the program will not be withdrawing groundwater that it has physically put into the aquifer through an active recharge program. Instead, it will require groundwater rights holders to forego pumping water that they are otherwise legally entitled to

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[6] City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 76-78 (Cal. 1943).

[7] Miller v. Bay Cities Water Co., 107 P. 115, ___ (Cal. 1910); Allen v. California Water & Tel. Co., 176 P.2d 8, ___ (Cal. 1947) (burden on appropriator to show existence of surplus); Monolith Portland Cement Co. v. Mojave Public Utilities Dist., 316 P.2d 713, ___ (Cal. Ct. App. 1957) (burden on off-tract user to show existence of surplus); 62 Cal. Jur. 3d, Water § 410 (1981).

[8] Rank v. Krug, 142 F.Supp. 1, 111-12, 113-14 (S.D. Cal. 1956), *affirmed in part and reversed in part*, California v. Rank, 293 F.2d 340 (9th Cir. 1961), *modified upon rehearing*, 307 F.2d 96 (9th Cir. 1962), *affirmed in part*, City of Fresno v. California, 372 U.S. 627 (1963), *overruled*, California v. FERC, 495 U.S. 490 (1990).

[9] CAL. WATER CODE § 1242 (West 1971).

extract in some years and to offset that forbearance by drawing more heavily on the aquifer in other years. The problem is that the contracting landowners have no better right to the underlying groundwater than do all of the other landowners overlying that same aquifer. The rights are "correlative", that is, of equal stature and limited by the principle of mutual avoidance of harm. Thus, in years of forbearance, the other pumpers would be entitled to extract the water that the program intended to store. In years of extraction, the contracting landowner's rates of withdrawal may impair the rights of the correlative pumpers.

Recognizing in the organizer a superior right to groundwater stored when surface water is used in lieu, could involve upsetting an established set of property rights and investment-backed expectations, something courts are typically loathe to do. Fortunately the only colorable claim of overlying groundwater users to water of Type 5 would result if the importer abandoned the imported water once it was in the ground. Delivery for surface use does not constitute such abandonment.[10] The important point when imported water is used is that the mass balance in the groundwater basin will be the same whether the water is actively recharged or delivered *in lieu* of groundwater pumping. In both cases during years or storage, more water is contained within the basin than would have been stored absent the program.

Of course, the problem associated with *in lieu* recharge may be avoided where groundwater basins have been adjudicated such that the particular extraction rights have been quantified. This is the situation with a number of groundwater basins in Southern California. A potential shortcoming of adjudication, other than the time and cost associated with the process, is that the final judgements in Southern California often proscribe out of basin transfers of groundwater. This may hinder the ability to recover groundwater of Type 5.

The technique of in lieu storage can be also used outside adjudicated groundwater basins, but special arrangements will be necessary. There are several potential approaches:

- The correlative rights problem can be avoided by bringing all of the correlative rights holders into the contractual arrangement, or mitigated by bringing most of them into it. The ability of any one rights holder to upset the program by withholding consent remains, however. This is were incorporation of storage entities as part of AB 3030 management plans could prove particularly beneficial.

- The program could be operated in a manner that would presumptively avoid injury to correlative rights holders by foregoing pumping for a period sufficient to assure that when accelerated pumping occurred, it would not disadvantage the correlative rights holders compared to the status quo. That might mean designing the program so that the number of sequential years of accelerated pumping was limited.

- Special legislation might be enacted to preclude suits against the program by non-contracting landowners where the groundwater that the program causes to be extracted in any one year was limited to amounts that could have been extracted in any previous year but for the forbearance imposed by the program. This would be a legislative interpretation of the "no harm" rule as applied in the narrow context of an in lieu groundwater banking program. While a general groundwater management regime may be beyond reasonable legislative expectations, a modest enactment of this sort may be realistic.

IV.3.2 What sort of entity should operate the program?

The organizer of the groundwater banking program will enjoy the best legal position to recover the groundwater that it has stored if it is a public agency managing groundwater of Type 5. Under these circumstances, the right to extract the stored groundwater enjoys a high priority. Such a right prevails over all rights except in the following circumstances:

> (1) It is inferior to the state-held public trust interest of the people of California, as are all usufructory rights;

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[10] City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 76-78 (Cal. 1943).

> (2) It is of equal priority with pueblo rights, but, since pueblo rights apply only to native water, disputes between the two result in apportionment to the importer of the quantity of groundwater attributable to imports;[11]
>
> (3) It is of equal priority with other public and private importers in the watershed of destination and use, but disputes between these parties are also resolved by apportioning to each importer "the amounts attributable to the import deliveries of each."[12]

An importer's right to recapture imported recharge water is established by manifesting such intent prior to importation.[13] A groundwater banking program is predicated upon such an intent.

The advantage of the program organizer being a public entity is that that status precludes the potential for adverse rights attaching to the program's stored groundwater through prescription. While CAL. CIVIL CODE § 1007 (West 1982) literally protects "any public entity" from prescription, the courts have been reluctant to afford the statute its broadest application[14] and may try to limit the definition of "public entity" to exclude some marginal parties. Therefore, care should be exercised in choosing or establishing the program organizer. Further research is needed regarding the outer bounds of the "public entity" definition. For instance, it would be useful to know whether a groundwater banking program organizer that was the creature of a memorandum of understanding between the state and federal government might qualify.

IV.3.3 Where should the program store the imported water?

In the most general sense, in order to simplify the legal situation, the target groundwater storage basin should be composed of percolating strata and be isolated from surface waters, such as streams or the underflow of streams. This would minimize the interplay of various legal doctrines, avoid factual disputes, and make the legal outcomes more predictable. As a result, the participants in the program will feel more secure about their rights and about the investments required to implement active recharge.

Under the groundwater banking arrangements explored here, however, water might be introduced into a groundwater basin at one location and extracted at another some distance away. This raises the question of the hydrologic interconnections that must be maintained between the imported recharge water and the extracted water in order to preserve the importer's preference right. "Imported water" is "foreign water imported from a different watershed."[15] The advantage of obtaining the rights of an importer is that California law gives high priority to these rights in order "to credit the importer with the fruits of his expenditures and endeavors in bringing into the basin water that would not otherwise be there."[16] Under this rationale, it would appear that the area of recharge must be hydrologically connected to the area of discharge such that the program is pumping groundwater that "would not otherwise be there" but for the recharge. In other words, the two areas much be sufficiently proximate and interconnected so that the recharge water would be expected to replenish the area of discharge within the timeframe of the two events.[17]

Establishing proximity and interconnectedness is very important. Many California cases determining groundwater rights turn on geohydrologic characteristics of the groundwater aquifers. In

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[11] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 288 (Cal. 1975).

[12] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 260-62 (Cal. 1975).

[13] City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 78 (Cal. 1943); City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 257-58 (Cal.1975).

[14] *See* City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 272, 274, 276 (Cal. 1975).

[15] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 261 n.55 (Cal. 1975).

[16] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 261 (Cal. 1975).

[17] One of the cases holds that it is possible to establish a right to imported water by making deliveries and withdrawals within one's own reservoir and alleging in a complaint that one intended to capture return flow from waters imported into the basin. City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 78 (Cal. 1943); City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 257-58 (Cal.1975). The issue, then, is whether the conjunctive use program would be viewed as delivering and withdrawing water from within the same underground reservoir.

addition to locating a storage site that is factually simple, it would be useful to locate one that is scientifically well-studied; ideally, one where the pertinent scientific facts have been determined in prior judgements. Such prior judicial fact finding may not be binding on parties to any future suit but would at least serve as an advance indicator of what the program might expect from future litigation.

IV.3.4 From what source(s) should the program obtain surface water for storage?

One consideration in selecting a source of program water is the fixed capital requirements of the program. If the program requires appreciable new physical infrastructure, as will likely be the case for a maximal program of groundwater banking, the costs of those capital investments will presumably have to amortized by the project itself over a period of time. In that circumstance, the program will require a reliable source of water over that same time horizon. If, by contrast, the program requires only limited capital investment, the program water can be intermittent or less reliable. Therefore, an early question to be resolved is whether the program can be based on an interruptible source of water, or does it require a durable source? The hydrologic distinction between capturing peak floods (intermittent) and re-operating reservoirs (reliable) will certainly bear on the appropriate response to this question.

IV.3.5 What parties should be involved?

The program organizer should seek contractual arrangements with parties owning land overlying groundwater since they may possess both spreading grounds and a right to extract groundwater. Their participation and cooperation may be secured by sharing the benefits of the program with them, either in terms of new water or monetary compensation. The presumption in this case is that the sharing of benefits made available to the overlying landowners will be sufficient to surpass the water management opportunities afforded by strictly local opportunities.

V. Workplan Step 3: Site Analysis

The hydrologic potential analysis described in Section III relied upon making assumptions about the ability to convey surface water and to store it in a suitable groundwater banking site. The assumed conveyance and groundwater storage capacities input for the simulated foothill reservoirs in CUP are presented in Table 13. By virtue of is large flows and significant existing surface water storage capacity, the Sacramento-Shasta system was accorded the largest portion of the assumed 2 MAF storage capacity. The relatively small Caleveras-New Hogan system lies at the other end of the conveyance/storage spectrum.

Table 13: Partition of System Capacity Among the Nine Simulated Rivers in CUP

River	Conveyance Capacity (cfs)	Provisional Storage (TAF)
Sacramento	648	370
Feather	518	296
Yuba	387	222
American	387	222
Mokelumne	260	148
Calaveras	130	74
Stanislaus	387	222
Tuolumne	387	222
Merced	387	222

At first glance, the values in this table may seem to indicate that conveyance infrastructure and potential storage sites are located in close physical association with each surface water system. Any such impression is an artifact of the way CUP operates as it simulates each river as an independent system. Given the highly engineered character of the Central Valley water system, it is more likely that surface waters from various rivers diverted as part of the groundwater banking program will co-mingle during the aquifer storage process. This section deals with identifying the sites which can provide the required aquifer storage resource.

Much work in this area has already been carried out by the CalFed Bay-Delta Program. as part of its Storage and Conveyance Component, the ongoing water planning forum produced and inventory of 17 potential groundwater storage sites. These were described in a matrix which included a number of attributes, including: the active storage capacity; the extent to which groundwater banking will alter groundwater elevations; required infrastructure; long-term regional groundwater conditions; and environmental concerns. Details of the active storage attribute, which total over 10 MAF are shown in Table 14.

Table 14: CALFED Estimates of Active Groundwater Storage Capacity

North of Delta Storage	Potential Storage	South of Delta Storage	Potential Storage
Butte Basin	470 TAF	Folsom S. Canal (east S.J. County)	860 TAF
Cache Creek Fan (Cache-Putah)	450 TAF	Kern River Fan	930 TAF
Colusa County	320 TAF	Gavelly Ford/Madera Ranch	350 TAF
Eastern Sutter County	470 TAF	Medota Pool (Westside)	900 TAF
Sacramento County	260 TAF	Mojave River	200 TAF
Stony Creek Fan	640 TAF	Semitropic WSD	1000 TAF
Sutter County	1180 TAF	Tuolumne/Merced Basin	1250 TAF
Thomes Creek Fan	220 TAF		
Yuba County	540 TAF		
Total North of Delta	**4,550 TAF**	**Total South of Delta**	**5,490 TAF**

The spatial distribution of these sites, along with other potential storage targets located in Southern California, is depicted in Figure 8. When compared with the hydrologic potential of the rivers considered in CUP (Table 11), the first observation one makes is that while most of the yield associated with reservoir re-operation will be generated in the Sacramento Valley, much of the potential storage is located south of the Delta. This raises the issue of how best to convey water across that keystone of the California water system. It should not be assumed that the ability to realize the full potential of groundwater banking in the Central Valley is neutral with regards to the three Delta conveyance opportunities under consideration by CalFed. What is required is operational analysis of specific groundwater banking opportunities which can explore the full implications of various assumption about the existence and operation of conveyance infrastructure. This sort of operational analysis which is presented in the Section VI.

By virtue of their inclusion in the CalFed inventory, the storage sites listed in Table 14 likely comprise a likely constellation of potential groundwater banking sites. NHI has neither the resources nor the desire to redevelop the CalFed list. From our vantage point, however, there are issues other than the active storage capacity which go to the relative merits of a particular groundwater banking site. In fact, prior to the release of the CalFed inventory NHI had already completed a first assessment of promising groundwater banking sites. Based on consultation with experts,[18] and on a literature review,[19] we chose several criteria for selecting candidate sites for new or enhanced artificial or *in lieu* recharge of ground water:

1. Aquifer storage capacity available for groundwater banking
2. Opportunities to solve collateral problems
3. Impact on habitat and species of fish and wildlife
4. Infiltration characteristics of soils and water courses
5. Hydraulic properties of aquifers
6. Extent of well development and yields of wells
7. The magnitude of surface water/groundwater interaction
8. Water quality effects of recharge
9. Land use effects of recharge

Figure 8: Spatial Distribution of Potential Groundwater Storage Sites in California

This listing has been selected to cover the broad range of conditions occurring in California with respect to groundwater banking. Appendix III contains the results of a survey conducted by NHI which sought out examples of where the convergence of these criteria have already generated interest or activity in groundwater banking. It is important to keep in mind that each site listed in the inventory could

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[18] Bertoldi, Gilbert, 1993, Senior Scientist, U.S. Geological Survey, Sacramento, California; Durbin, Tim, 1993, Professional Engineer, vice-president, Hydrologic Consultants, Inc., Davis, California; Fielden, John R., Hydrologist, 1993, California Dept. of Water Resources, Sacramento, California; Wilson, Laurence, April, 1993, Ground Water Protection Supervisor, Santa Clara Valley Water District, San Jose, California.

[19] Asano, Takashi, and others, 1985, Artificial Recharge of Groundwater, Butterworth Publishers, Boston.

potentially become more productive with an infusion of new yield derived from reservoir re-operation. The nature and importance of these criteria are explored in greater detail in the following comments.

The volume of water which can be stored in the subsurface is dependent on the **aquifer storage capacity**. At an given moment, however, most of the water in storage will be the result of basin scale hydrologic processes. An intentional program of groundwater banking seeks to capitalize on the increment of storage capacity which could be integrated with the yield estimated in Section III. The challenge is defining the increment of storage capacity available to the groundwater banking program.

In areas of severe groundwater depletion that increment of storage clearly exists in the form of a persistent cone of depression. The presence of a cone of depression on the water table surface, a fairly common phenomenon in the Central Valley south of the Mokelumne River drainage, indicates that local pumping historically exceeded the natural recharge to the aquifer. If the cone is stable, then a water balance has likely been re-established via enhanced seepage from overlying rivers and streams in response to the increased hydraulic gradients associated with the drawdown feature. Defining the increment of groundwater storage in this case involves a fairly straight forward computation of filling the basin with known quantities of water and discounting the reduction in the induced seepage from overlying rivers and streams. This increment of enhanced stream flow would be a direct environmental benefit of the program. In addition, the net rise in the water table during periods of aquifer storage would have direct and quantifiable local benefit relative to the persistent cone of depression currently plaguing local groundwater users. The primary disadvantage of utilizing this increment of storage are the pumping costs associated with recovery from a deep cone of depression and the need to carry out a period of storage before any recovery can be achieved.

A second increment of storage available for groundwater banking should be viewed in more speculative terms. In locations where there has been no sustained, long-term imbalance between basin scale hydrologic process, as is commonly the case in the Sacramento Valley, the water table is generally more stable and closer to the surface than in zones of persistent dewatering. In order to create the increment of storage required for groundwater banking, recovery, either through increased local reliance on groundwater pumping or though the export of groundwater, must precede storage. This is somewhat akin to the situation in the drought water bank of the early 1990’s when Sacramento Valley farmers sent groundwater to water strapped communities in Southern California in exchange for monetary compensation. Achieving this increment of storage essentially involves treating the aquifer as a direct extension of the reservoir. As in a reservoir where the lake surface fluctuates from month to month, the end result of this integration would be a water table which fluctuates within a prescribed management range. While a case can be made that the optimal overall system yield will emerge from this integration it is more difficult to demonstrate the local benefit of this type of storage and recovery.

For that reason we initially focused our attention in this feasibility study on zones where groundwater overdraft has already created a cone of depression. This focus should not be understood as completely discounting the potential role of the more integrated form of groundwater banking. In fact, given the imbalance in hydrologic potential towards the Sacramento Valley (Table 11) and the potential complexity of conveying water across the Delta, it may ultimately be necessary to explore the full range of Sacramento Valley alternatives. The premise of the program, however, should remain the same whether storage takes place in persistently de-watered or stable hydrologic regimes. Namely the use of any available aquifer storage resource must provide sufficient local benefit to inspire substantial local enthusiasm.

The best way to motivate local enthusiasm for groundwater banking is to demonstrate that implementation of the program might help **solve collateral water problems**. Our starting premise for this assertion is that even in relatively stable hydrogeologic provinces, water managers face challenges which call for action. These challenges often involve water quality consideration, the desire to resolve emerging conflicts between municipal and agricultural water use sectors, or the need to redress the degradation of aquatic habitat. In all such cases, controlling the rate and place of ground water recharge and pumping may create opportunities to accomplish local water management goals which would go unrealized save for the introduction of new yield into the system. Examples of the types of collateral problems which could be resolved in this manner include land subsidence and ground water quality degradation in Yolo County and increasing pumping lifts in eastern San Joaquin County.

Attention must also be paid to the **impacts, both positive and negative, which groundwater banking can have on fish and wildlife**. Appendix IV includes our assessment of some potentially negative impacts of groundwater banking which must be resolved. Commonly, groundwater recharge sites are viewed as wetlands conducive to enhanced wildlife management opportunities. Wildlife experts[20] remind us that to be beneficial to wildlife, water must be provided to an environment, in the right amount, at the right time, in suitable quality; and, the supply must be reliable. It would seem that specific benefits to wildlife could be built-in to many recharge projects, to create and maintain wetlands, where needed, or to increase the base flow of small streams through raising ground water levels. Another, perhaps more far reaching, environmental benefit of groundwater banking goes beyond the local impact of a flooded recharge basin. This benefit goes to the aquatic eco-system restoration opportunities which would have otherwise been missed without the added water management flexibility associated with the potential yield increase from groundwater banking. An examples of this type of benefit include the potential to enhance Delta outflow by storing groundwater in San Joaquin County and to restore the anadramous fishery in the San Joaquin River by banking groundwater near the Gravelly Ford reach of the river.

Aquifer recharge, the first of two central operations in a groundwater bank, occurs primarily by spreading water on land and in stream beds, or, or by filling percolation ponds. In all cases, **the infiltration characteristics of soils and sediments** determine the rate at which surface water becomes ground water. Clayey soils and sediments tend to inhibit infiltration. Generally, suitable soils must overlie permeable sediments in order to provide the physical environment essential to recharge the water table. Soil surveys developed by the U.S. Natural Resources Conservation Service provide information adequate to evaluate the recharge potential of soils, but, information on underlying sediments usually does not extend beyond the description of parent material.[21] Work conducted by the USGS in the Tulare Lake Basin, for example, identified large areas in which shallow clays underlying surface soils[22], precluding the development of any effective program for recharging ground water reservoirs, even though surface soils accept water readily. Other USGS studies in eastern San Joaquin County and along the Gravelly Ford reach of the San Joaquin River reveled conditions conducive to groundwater banking. When aquifer recharge is accomplished via *in lieu* substitution the pre-existence of extensive groundwater pumping is required. By substituting surface water for this pumping, ground water storage can be increased. In order to estimate the potential for *in lieu* groundwater recharge, information must be developed on the amount of pumping which is likely to occur during years of normal or above normal precipitation. An inventory of agricultural pumping in Yolo County is an example of information required in this case[23].

The rate at which aquifers can be discharged by pumping wells, the second of the two central operations of a groundwater bank, is dependent on **the hydraulic properties of the aquifers**, the spatial extent of these aquifers, and on the hydraulic head created by pumping.[24] Although specific investigations are required to quantify these properties, a history of groundwater use in target areas is a good indication that under natural hydrologic conditions these conditions favor aquifer storage and recovery. In selecting a site, the presence of groundwater wells should be the minimum threshold for consideration. **The extent of well development and the long term yield** of large volumes of ground water to wells suggests a favorable physical environment for recovery.

The magnitude of surface water/groundwater interaction at any given site may influence groundwater banking opportunities. In the San Joaquin Valley, where past overdrafts have dropped

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[20] Moore, S.B., and others, September 1990, "Fish and Wildlife Resources and Agricultural Drainage in the San Joaquin Valley, California: Technical Report of the San Joaquin Valley Drainage Program, Sacramento, California.

[21] Bullard, Gary, 1993, Senior Soil Scientist, U.S. Natural Resources Conservation Service, Davis, California, personal communication.

[22] San Joaquin Valley Drainage Program, September, 1990, "A Management Plan For Agricultural and Subsurface Drainage and Related Problems on the Westside San Joaquin Valley": Sacramento, California.

[23] Borcalli, Fran, 1992, "Yolo County Water Plan Update,"Report to Yolo County Board of Supervisors, Woodland, California; Jenkins, Mimi, Sept., 1992, "Yolo County, California's Water Supply System: Conjunctive Use Without Management," MS. Thesis, Dept. of Civil Engineering, University of California, Davis, California.

[24] Freeze, R.A. and Cherry, J.A., 1979, Groundwater, Prentice-Hill, Englewood Cliffs, NJ.

groundwater levels far below ground level, the degree to which adding groundwater storage may impact streamflow levels is relatively small. However, in many locations within the Sacramento Valley, groundwater storage may lead to increases in surface flows. Conversely, groundwater withdrawals could lead to reductions in surface flows. These kinds of interactions reduce the benefits of groundwater banking and increase the complexity of storage accounting. What is required is a thorough understanding of basin hydrogeology. Within California, there is a wide range in the certainty of knowledge of the hydraulic properties of specific aquifers.[25] Some water user organizations, such as the Turlock and Modesto Irrigation Districts, are well-armed with information to plan and operate an artificial recharge program, as part of a conjunctive use strategy. Others, like the Butte Basin Water Users Association, are in the process of developing the quantitative models and monitoring devices useful for participation in such programs. This information is lacking in regions such as Tehama County.[26] Wherever groundwater banking ultimately occurs, detailed hydrogeologic analysis will be required.

A review of the history of irrigation and ground water recharge in California,[27] shows the importance of considering **the water quality effects of recharge**--whether that recharge is coincidental or planned. Positive or negative effects can be produced in soil water or in underlying ground water reservoirs through the introduction of surface water of a certain quality. For example, some of the soils of the eastside San Joaquin Valley (Fresno area) are too sodic to be recharged effectively with Sierra water, without the addition of gypsum to the soils.[28] Looking for a "win-win" situation, the San Joaquin Valley Drainage Program, [29] analyzed the feasibility of exporting gypsiferous drainage water to irrigate these lands and recharge ground water. The concept was feasible, technically, but could not overcome political objections.

Most information on **land use effects of ground water recharge** is anecdotal, obtained from discussions with various water experts. In San Bernadino County, artificial recharge was halted in one locale, when rising ground water levels caused clays to swell and threaten the structural integrity of piers in a highway overpass.[30] In highly urbanized Santa Clara County there have been chronic complaints, and lawsuits, from residents adjacent to percolation ponds.[31] Nearby residents have alleged the creation of mosquito problems, marshy soils, and dangerous nuisances from open water bodies. Because of these and associated cost factors, ground water recharge in urban areas is most effectively conducted in natural or modified stream courses.

In light of resource limitations, NHI did not conduct detailed analysis of each of these attributes at all of the twenty potential sites in Figure 8. Our reconnaissance of the landscape, however, lead us to three locations where a convergence of groundwater banking attributes seems to exist. While by no means claiming that these are the sites which must ultimately store yield generated through pre-delivery[32], these are striking examples of the ability of groundwater banking to help meet: 1.) water management objectives; 2.) eco-system restoration objectives; and 3.) a combination of both these objectives.

<u>Cache-Putah Basin</u>. Cache and Putah Creeks are significant westside tributaries of the Sacramento River. Historically, flows in these creeks recharged groundwater below Yolo County through instream hydraulic connection with the aquifers which provide much of the county’s municipal and agricultural water supply. Recently the intensity of local reliance on groundwater has combined with the out-of-basin export of water from Putah Creek and the mining out of the instream gravel in Cache Creek to create nagging problems

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[25] Durbin, Tim, 1993, Professional Engineer, vice-president, Hydrologic Consultants, Inc., Davis, California, personal communication.

[26] Durbin, Tim, 1993, Professional Engineer, vice-president, Hydrologic Consultants, Inc., Davis, California, personal communication.

[27] Prokopovich, Nikola P., April, 1989, "Irrigation History of the West-Central San Joaquin Valley" : U.S. Bureau of Reclamation Contract Report No. 7-PG-20-03920, Sacramento, California.

[28] Sposito, Garrison, and others, 1987, "Chemical Effects of Saline Drainage Waters on Irrigated San Joaquin Valley Soils": Calif. Water Resources Center, Univ. of Calif. Contribution No. 196.

[29] Hansen, B.R., and others, June, 1990, "An Assessment of Blending Westside Drainage Water with Friant-Kern Canal Water for Increasing Infiltration Rates": U.S. Bureau of Reclamation Contract Report No. 9-FC-20-08070.

[30] Fletcher, G. Louis, December, 1992, General Manager and Chief Engineer, San Bernadino Valley Municipal Water District, San Bernadino, California, personal communication.

[31] Wilson, Laurence, April, 1993, Ground Water Protection Supervisor, Santa Clara Valley Water District, San Jose, California.

[32] Tocay Dudley of the DWR Central District has been directing studies of groundwater storage opportunities in Yuba, East Placer, Yolo, and Sacramento counties. These may supplement the preliminary list outlined here.

with groundwater overdraft, land subsidence, and deteriorating ground water quality.[33] Despite the high cost and political uncertainty, these challenges have prompted both agricultural and municipal water providers to initiate planning to secure a Sacramento River water right. Such a claim would certainly be facilitated by increasing the available yield through reservoir re-operation. This could be accomplished by developing new off-stream percolation ponds or negotiating *in lieu* arrangements with local farmers which would be supplied through an extension of the Tehama-Colusa Canal. In exchange for this introduction of water, the Yolo water users could continue to allow the Yolo County ground water reservoir to be used as part of the drought water bank which performed well during the heart of the 1987-92 drought. To garner local support for such a scenario, however, this approach needs to be compared with purely local opportunities to meet water management objectives.

Gavelly Ford/Madera Ranch. As mentioned in Section II, operation of the Friant Unit on the San Joaquin River has lead to the virtual de-watering of the river below Friant Dam. Other then during occasional flood flows which spill from Millerton Lake, nearly all of the water in the San Joaquin in diverted to provide water for irrigation. Obviously this severe alteration of the hydrograph in the San Joaquin River has had a dramatic impact on fish. In particular, runs of anadramous fish were decimated. Enter the Anadramous Fish Recovery Act spawned by the CVPIA and its call for a doubling of the number of anadramous fish in the Central Valley, and restoration of the San Joaquin emerges as a promising management alternative. The challenge is to achieve this eco-system objective in a manner which minimizes negative impacts on existing water users. Groundwater banking opportunities in an expansive cone of depression below the Gravelly Ford reach of the San Joaquin and the adjacent Madera Ranch site could assist in removing political opposition to an environmental goal.

East San Joaquin County. Two associated ground water basins in this area are overdrafted and the northernmost basin, which is used directly for water supply by the city of Stockton, is experiencing intrusion of brackish water from the Sacramento-San Joaquin Delta. There is an overall shortage of both ground water and surface water, particularly surface water for environmental releases to the Stanislaus River Basin. Plans to extend the Folsom South Canal in order to use imported Ameircan River surface water for aquifer recharge have been discussed for many years although a consulting firm hire by local water districts[34] found that the structural modifications needed to facilitate large-scale groundwater banking would be formidable. Nevertheless, the strategic location of the ground water basins with respect to the Delta, make this a viable candidate area because water stored in this location would be well placed to help improve the export and environmental water management objectives in the Delta which may be compounded by certain Delta conveyance options under consideration by CalFed.

It is our hope that detailed operational analysis of the Cache-Putah, east San Joaquin, and Gravelly Ford/Madera Ranch groundwater banking sites, which is found in Section VII, will motivate additional support to bring the remaining sites under similar scrutiny.

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[33] Jenkins. Mimi, September 1992, "Yolo County, California's Water Supply System: Conjunctive Use Without Management," M.S. Thesis, Department of Civil Engineering, University of California, Davis.

[34] California Department of Water Resources, 1990, "Stanislaus and Calaveras Conjunctive Use Program," unpublished paper by Don Fisher, Senior Engineer, Sacramento, California.

VI. Workplan Step 4: Operational Analysis

In order to analyze both how any specific groundwater banking interventions might function and how they might interact with other features of the Central Valley water system, a simulation model is required. One of the key elements of an intentional program of groundwater banking will certainly be specific distribution and conveyance arrangements of both a structural and an institutional nature. An exploration of the ramifications of these arrangements is needed. In California, the type of exploration envisioned for this operational analysis has traditionally relied on the use of DWRSim, a simulation model of the State Water Project which has evolved into the standard reference for modeling the Central Valley water system.

In the current planning context, where the California water community is being encourage to pursue "fresh thinking rather than entrenched ideologies"[35] DWRSim is somewhat constrained by its attention to the details and nuances of the current system. It is not easy to reprogram DWRSim to model radical departures from the current system such as reservoir re-operation and the integration of the groundwater banking site in Table 14 into the Central Valley water system. To accomplish this exploratory analysis NHI initiated a collaborative program with several California water partners to identify an appropriate screening level river basin simulation model. The goal of the effort was to develop a tool which could help identify water management arrangements which show promise and which merit further attention. The premise behind this search was that identifying a sub-set of promising arrangements could provide a sharper focus for subsequent refinement of the more cumbersome DWRSim model.

To develop this screening tool NHI joined with the CalFed Bay-Delta Program, the US Bureau of Reclamation, the US Fish and Wildlife Service, and the Metropolitan Water District of Southern California to form the Joint Technical Unit (JTU). This grouped selected and guided the enhancement of the Water Evaluation and Planning system, or WEAP, developed by Tellus Institute. WEAP is a flexible water balance modeling tool conducive to the initial evaluation of management options at a system level. Unlike most river basin models, it effectively integrates supply, operation and demand. It is also highly flexible in that it can be easily reconfigured to screen emerging management options and to flesh-out those which appear promising.

In order to make WEAP more appropriate for the Central Valley, the JTU funded two phases of model enhancement. Phase I included the development of a conjunctive use node to simulate the intentional transfer of water from the surface water system to a target groundwater banking site. The magnitude of the simulated transfer is the minimum of the excess surface supply during a given month, the available storage capacity in the aquifer, and the transmission capacity available to effectuate the transfer. A second Phase I modification involved the development of an active diversion feature. This feature mimics the operation of a single canal which services multiple points of demand; a common feature in the water management landscape of California. A second phase of modifications funded by the JTU fell into three categories: graphical output enhancements, water year type controls, and refinement of the conjunctive use node. The enhanced version of WEAP was delivered to the JTU in April, 1998.

Since receiving the enhance software, NHI has carried out operational analysis on the three specific groundwater banking opportunities identified as the end of Section V: 1.) the Cache-Putah Basin; 2.) the Gravelly Ford/Madera Ranch reach of the San Joaquin; and 3.) east San Joaquin County. Respectively, these were selected as particularly strong examples of how groundwater banking can help meet: 1.) local and regional water management objectives; 2.) eco-system restoration objectives; and 3.) a combination of both these objectives. It must be reiterated that NHI chose these examples only to demonstrate the far-reaching benefit which can be realized through the implementation of a maximal scale program of groundwater banking. The analysis presented in this section should not be interpreted as an endorsement of these particulate sites over the other contained in Table 14. In fact, NHI hopes that the following demonstration of WEAP's ability to screen potential groundwater banking sites will motivate the additional resources required to complete operational analysis on all potential storage sites.

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[35] Deep Water Thinking, Sacramento Bee Editorial, November 18, 1998.

VI.1 Meeting Water Management Objectives: The Cache-Putah Basin

Located in the southwestern Sacramento Valley between Cache and Putah Creeks, the Cache-Putah Basin (Figure 9) serves as an important source of water for both the agricultural and urban communities of Yolo County. Under current operating arrangements, surface water from Cache Creek, regulated by dams at the outlet of Clear Lake and on Indian Valley Reservoir and diverted at Capay, provides irrigation water for farms west of Davis and Woodland. The water in Putah Creek has been developed for use in Solano County and much of the flow is exported from the basin towards the south at a point east of Winters. In the extreme north of Yolo County, surface water is also available from the Tehama-Colusa Canal, and the Colusa Drain which convey Sacramento River water from points of diversion located in the Sacramento Valley to the north of the county. In the eastern portion of the Yolo County, water is taken directly from the Sacramento River for both irrigation and the municipal supply for the City of West Sacramento.

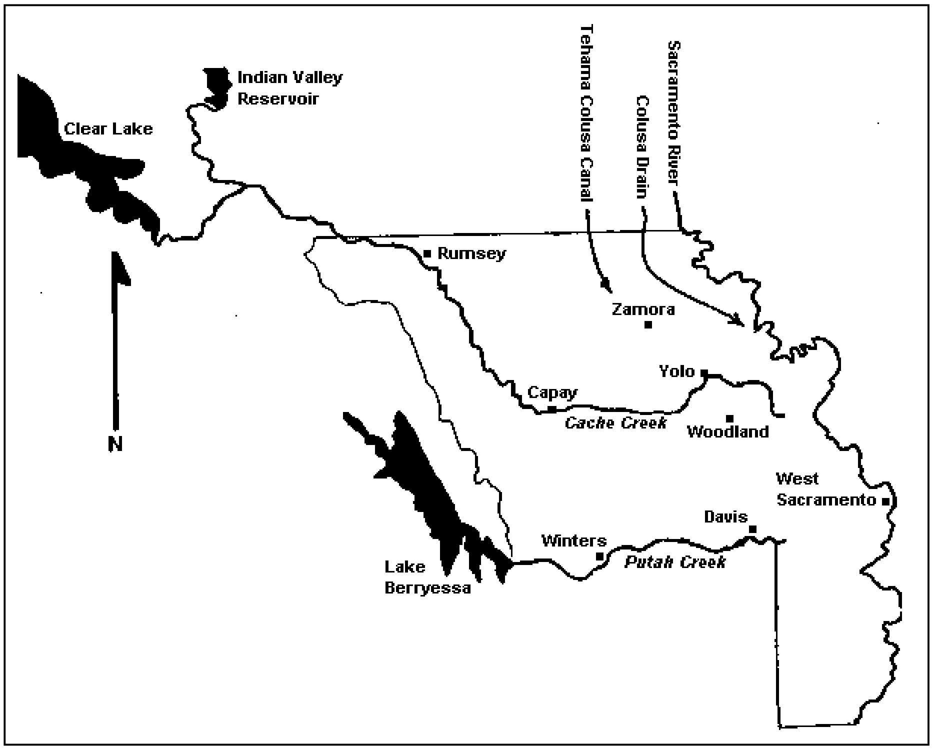


Figure 9: The Cache-Putah Basin

In spite of the availability of surface water from Cache Creek and the Sacramento River, there remain regions of Yolo County which rely exclusively on groundwater for supply. Overlying a map of the areas in which surface water is available with a map of the primary groundwater sub-basin of the Cache-Putah aquifer (Figure 10) reveals that a substantial portion of the land overlying the Lower Cache-Putah Sub-Basin has no access to surface water. This region includes Yolo County's principle cities, Davis and Woodland, as well as some of the most productive agricultural land in the Central Valley.

The result of this heavy reliance on pumped groundwater has been the development of a cone of depression in the water table of the Lower Cache-Putah Sub-Basin. The dimensions of this feature following the wet winter of 1993 are shown in Figure 11. Water table elevation data suggest that depending on hydrologic conditions this cone of depression will vary in size and depth, although it remains persistent. This feature is a remnant of the much more extensive depression which plagued the county prior to the construction of Indian Valley Reservoir on the North Fork of Cache Creek in the 1975. The enhancement of surface supplies afforded by the reservoir has allowed for a reduction in groundwater pumping, improving the water balance in the county. Nonetheless, the nagging persistence of this overdraft feature continues to create concern over land subsidence, the initiation of groundwater flow patterns which threaten water quality, and increasing pumping costs.

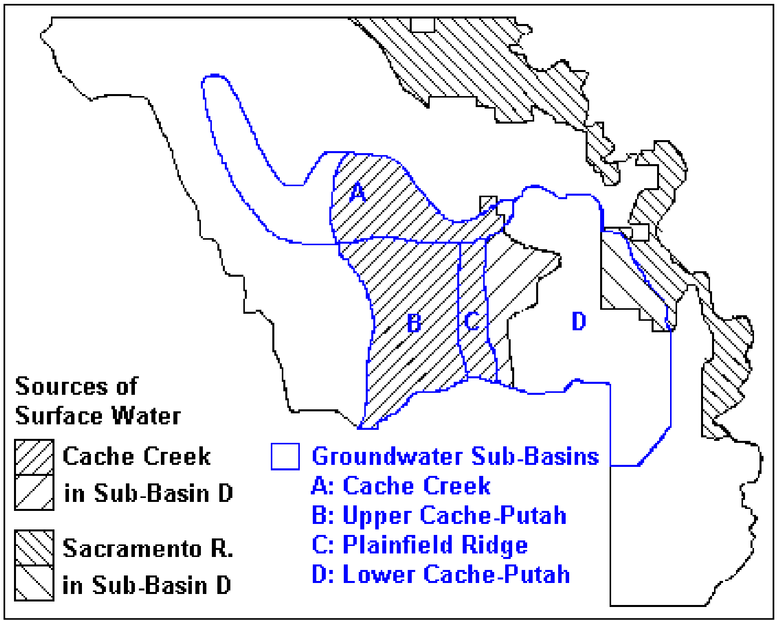


Figure 10: Composite Map of Groundwater Basins and Surface Water Service Areas

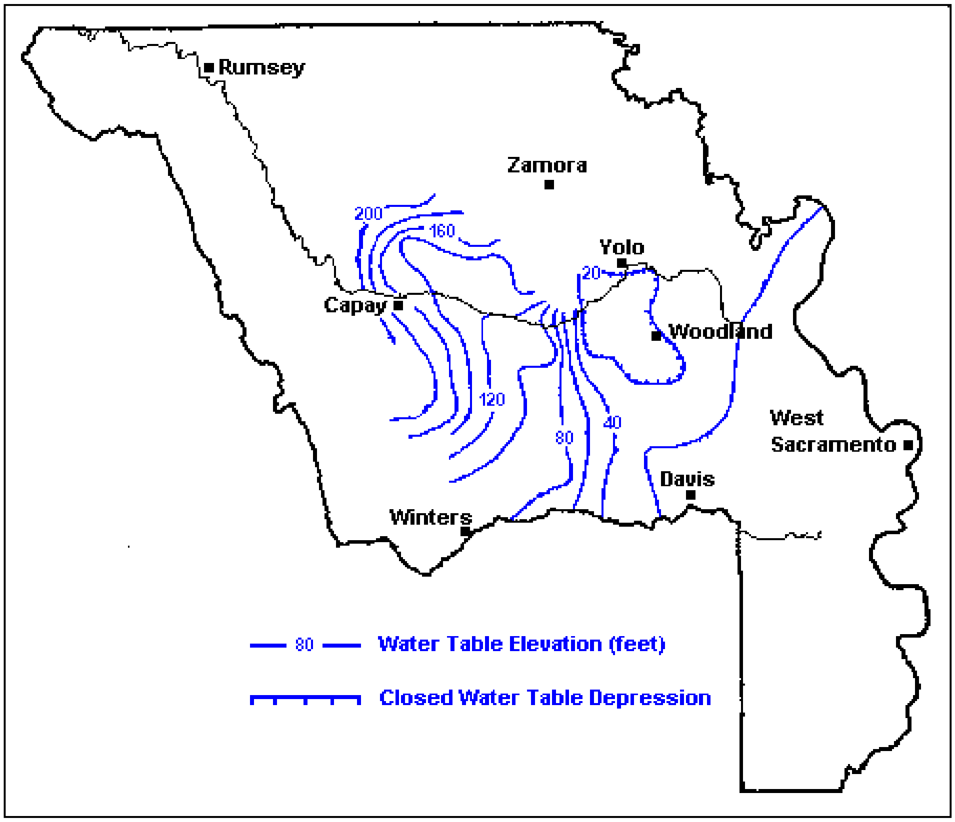
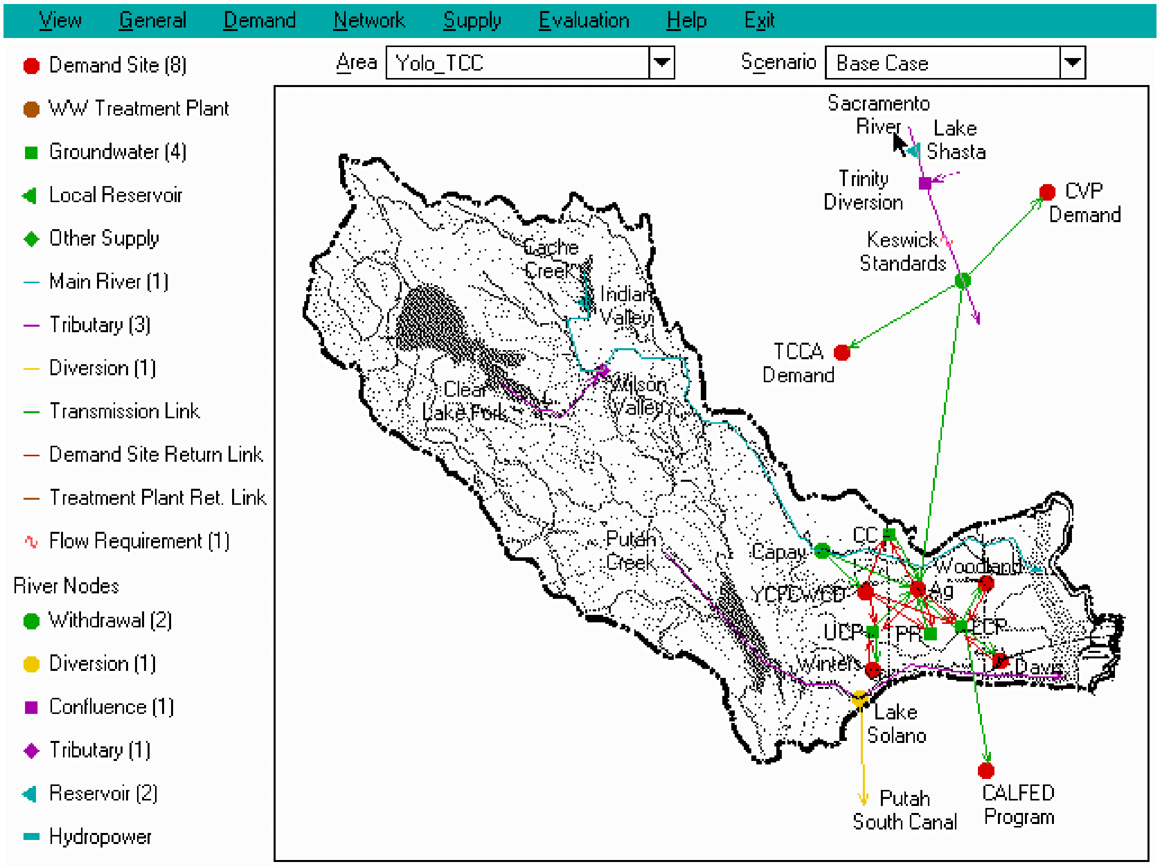


Figure 11: 1993 Cone of Depression in the Lower Cache-Putah Sub-Basin

In response to these threats, local water managers have proposed many alternatives. One is expand the area receiving surface water from Cache Creek as part of a local *in lieu* substitution program.

An alternative to this purely local response might be integration of the aquifer storage resource in the Lower Cache-Putah Sub-Basin into the broader Central Valley water system. Such integration could potentially assist in capturing some of the yield which could be generated through re-operation of Shasta Dam. It could be accomplished by implementing the long discussed extension of the Tehama-Colusa Canal into central Yolo County. With the connection in place, imported surface water could be used to implement *in lieu* transfers with farms overlying the dewatered portion of the Lower Cache-Putah Sub-Basin. Operational analysis using WEAP was conducted to explore the relative advantages and dis-advantages of these two water management strategies.

This was accomplished by configuring WEAP to represent the major features of the hydrologic system. Within the Cache-Putah Basin the essential features include the major sources of water supply, the principle points of demand, and existing and proposed hydraulic infrastructure. These are depicted in the WEAP Network Configuration shown in Figure 12. The data used to define these nodes was gathered primarily from the pages of the detailed inventory of Yolo County water developed by Jenkins (1992)



Area Yolo_TCC

Scenario Base Case

Figure 12: WEAP Cache-Putah Basin Network Configuration

The network configuration in Figure 12 includes all of the elements required to simulate three scenarios: the current base case; *in lieu* groundwater banking using surface water from Cache Creek; and *in lieu* groundwater banking using surface water from the Sacramento River. In the base case the transmission links joining the Capay and T-C Canal withdraw nodes with the Ag demand node in Yolo County are inactive. For the Cache Creek *in lieu* scenario the Capay link is activated and Indian Valley Reservoir is re-operated to pre-deliver water to the Ag node when surface water is available. In this scenario, the operation of Clear Lake Dam does not change as the YCFCWCD annually takes as much water as it can from that resource. By activating the transmission link between the T-C Canal and the Yolo County Ag demand node, Central Valley scale integration can be simulated. In this case Lake Shasta is re-operated to transfer available surface water to Yolo County for *in lieu* substitution. Broad water supply benefit can be achieved by activating the transmission link between the Lower Cache-Putah Sub-Basin and the CALFED Program demand node which calls for supplemental supplies during dry and critical water years.

Realization of either scenario will require the support of Yolo County water managers, stakeholders and politicians. From this perspective there are two essential question in evaluating the relative merits of the various approaches. Does a the water management intervention reduce the threats posed by the existence of a persistent aquifer draw down feature? How do existing stakeholders fare under the modified arrangements? Responds to both questions relies upon the establishment of a base reference.

Figure 13 is a simulated forecast of storage in the Lower Cache-Putah Sub-Basin under existing management arrangements and projected demand, assuming that the hydrologic record from 1972-1992 recurs between 1990 and 2010. The implication is that absent management intervention there will be a continued depletion of the groundwater resource in Yolo County. This change would likely strength the water quality and land subsidence threats faced by the county.

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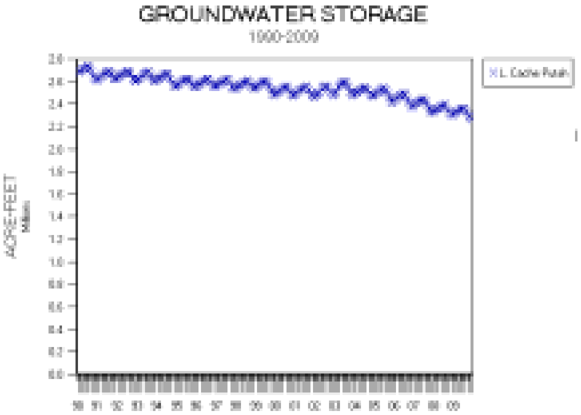


Figure 13: Simulated Groundwater Storage in the Lower Cache-Putah Sub-Basin Under Existing Arrangements

Recognizing this likely trend, local water managers have proposed the Cache Creek *in lieu* substitution scenario as a potentially beneficial strategy. In terms of the first essential question, by reducing groundwater pumping at the Ag demand node through the delivery of surface water the simulated decline in aquifer storage substantially reduced (Figure 14). In this case, rather than demonstrating a steadily decreasing trend, aquifer storage appears to fluctuate within an acceptable management range. The decline in storage at the end of the simulation corresponds to the recurrence of the 1987-1992 drought.

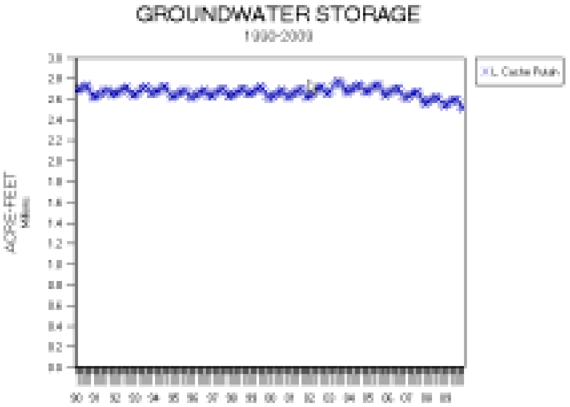


Figure 14: Simulated Groundwater Storage in the Lower Cache-Putah Sub-Basin Under Local *In Lieu* Arrangements

Increasing the area which receives water from Cache Creek, however, will presumably place a heavier burden on the surface water infrastructure on Clear Lake and Indian Valley Reservoir. In terms of the second essential question, this could make it more difficult to supply water to existing YCFCWCD customers. Figure 15 compares the difference in supply requirement coverage, or the extent to which demand is satisfied, under the proposed local *in lieu* substitution program as compared with the current arrangements. Relative to the base case, the heavier draw on the local surface water system would apparently cause the existing YCFCWCD customers to experience a decline in service relative to the level they would have received absent the program. Building a case for local *in lieu* substitution could be hampered by the decline in service experienced by an important group of stakeholders.

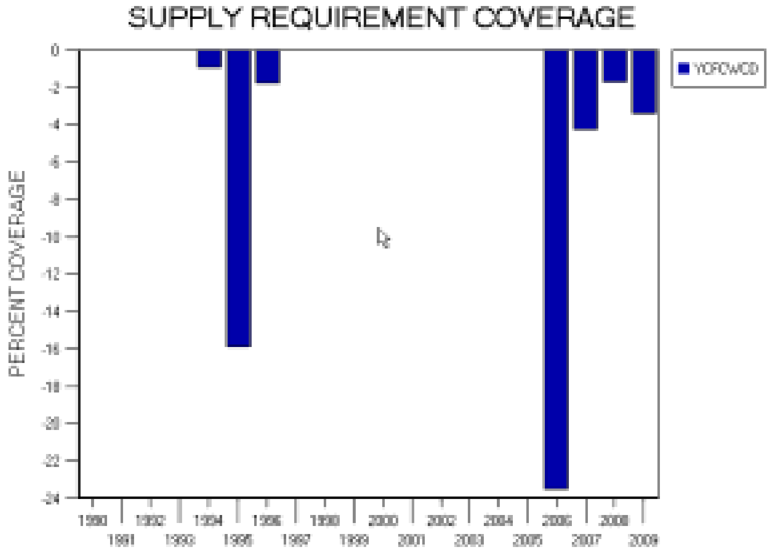


Figure 15: The Difference Between the Percent of the Supply Requirement (Demand) Coverage in the Base Case and the Local *In Lieu* Program Using Surface Water from Cache Creek

Carrying out *in lieu* arrangements with agricultural interests overlying the Lower Cache-Putah Sub-Basin using surface water made available through re-operation of Shasta Dam also mitigates the steady decline in aquifer storage predicted under the base case (Figure 16). The wider fluctuations in storage experienced under this arrangement relative to the local approach are the result of the more aggressive storage and recovery program carried out under integration into the Central Valley water system.

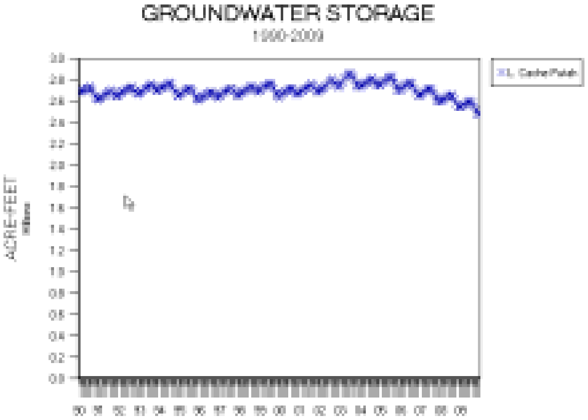


Figure 16: Simulated Groundwater Storage in the Lower Cache-Putah Sub-Basin Under Central Valley *In Lieu* Arrangements

Under this integration, no re-operation of the Cache Creek surface water system occurs and therefore existing YCFCWCD customers would experience no decline in service relative to the base case. Under this scenario, however, statewide water stakeholders would anticipate gaining some water supply advantage. In the simulation this is achieved by activating a 100 cfs transmission link between the Lower Cache Putah aquifer and the CALFED Program demand node. This node calls for 20 TAF of water during dry water years and 100 TAF during critical years. Under these arrangements the pattern of water supply enhancement which could be generated is shown in Figure 17.

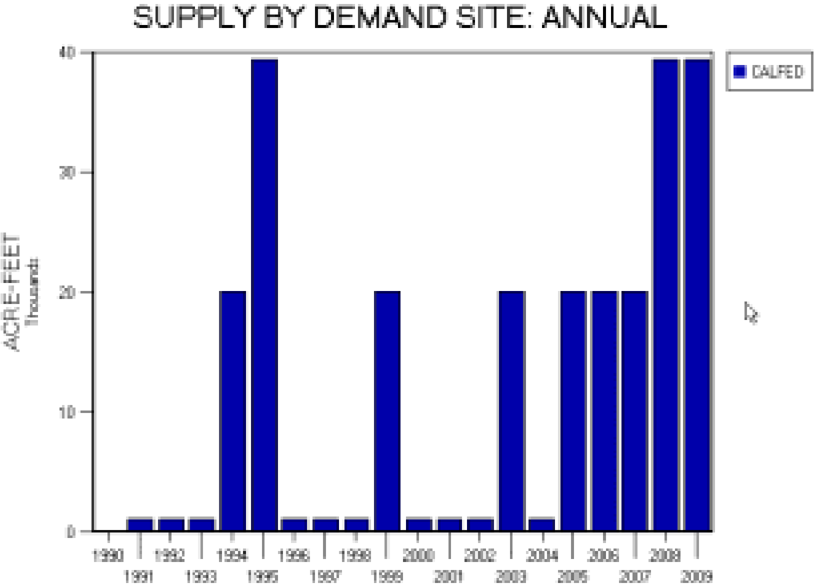


Figure 17: Simulated Water Supplies Enhancement for the CALFED Program Under a Central Valley *In Lieu* Substitution Program in the Lower Cache-Putah Sub-Basin

Increasing the capacity of the transmission link between the aquifer storage and the CALFED demand node could enable more complete coverage of the dry year demand, although potentially at the expense of stabilizing groundwater storage in the Lower Cache Putah Sub-Basin. As it is, there is a net transfer of water from the CVP storage system into the Yolo County groundwater system. Achieving a more balanced distribution could be achieved by fine tuning the capacities of important transmission links. The important implication of these simulations, however, is that without some sort of intervention groundwater levels in Yolo County will likely continue to decline and that the opportunity to negotiate storage and recovery arrangements with the managers of the Central Valley water system could provide water supply benefits both locally and a broader scale.

VI.2 Meeting Environmental Objectives: Gravelly-Ford/ Madera Ranch

In addition to facilitating the achievement of water supply objectives, groundwater banking can also assist in achieving important eco-system restoration objectives. One particularly exciting opportunity would be the restoration of the anadramous fishery in the San Joaquin River below Friant Dam. This fishery was completely decimated when the U.S. Bureau of Reclamation impounded the San Joaquin River and diverted it for use outside the basin. The hydrologic impact of this manipulation is depicted in Figure 18 which presents measured flows at the USGS *San Joaquin R Bl Friant Ca* gauge. Once the Friant Unit of the Central Valley Project went on-line, base flows in the San Joaquin were drastically reduced, with only peak event spills from Millerton Lake passing downstream. This flow regime proved incapable of supporting spawning and rearing salmon and steelhead. Reversing the loss of this fishery could provide substantial momentum towards meeting the AFRP anadramous fish doubling narrative standard. NHI believes this could be achieved by integrating the substantial groundwater banking opportunity at the Gravelly Ford/Madera Ranch into the surface water system in the San Joaquin Valley.

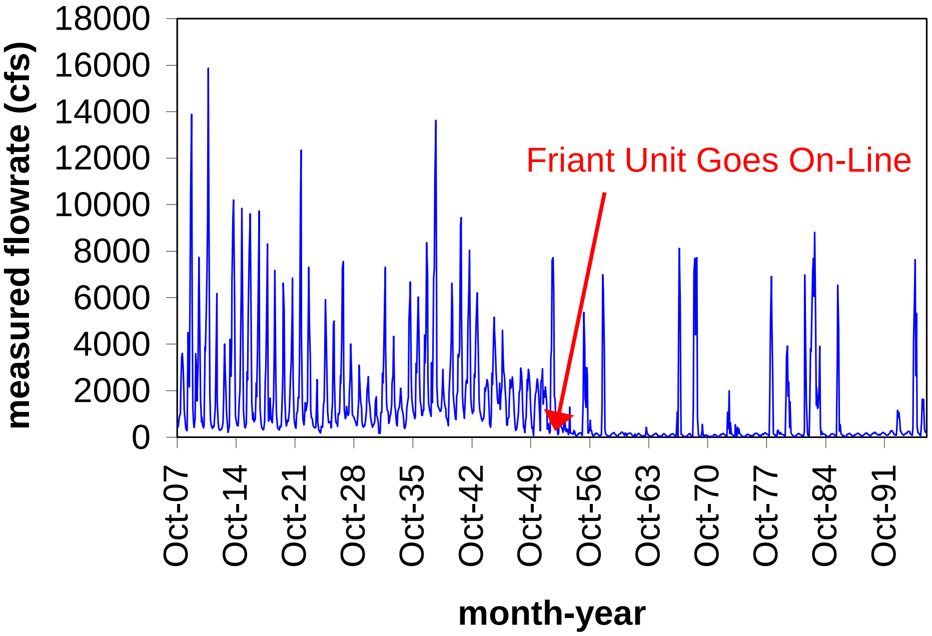


Figure 18: Measured Flows at the USGS *San Joaquin R Bl Friant Ca* Gauge Before and After the Construction of the Friant Unit of the Central Valley Project.

This system, depicted in Figure 19, includes the Delta-Mendota Canal which was constructed at the same time as the Friant Unit to provide roughly 800 TAF of replacement Delta water to exchange contractors holding water rights on the de-watered San Joaquin River. Later, the California Aqueduct system, including the Delta pumps at Clifton Court, the regulating facility San Luis Reservoir, and various pumping plants, was constructed by the State of California to convey water to the southern San Joaquin Valley and then over the Tehachapi Mountains to Southern California. The Cross Valley Canal, financed by Kern County interests, was constructed to capitalize on the water management flexibility which could be achieved through exchanges between the Delta and San Joaquin River systems.

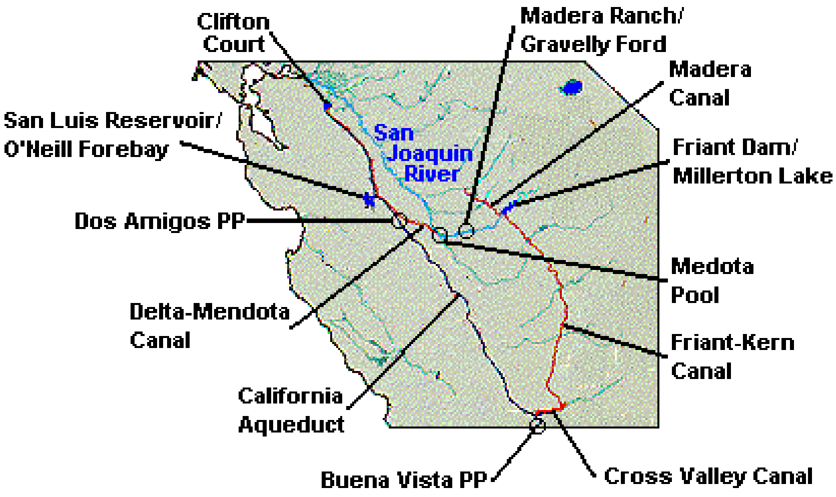


Figure 19: Important Elements of the San Joaquin Valley Water System

It is this type of flexibility which NHI would like to expand upon into order to profit from the substantial groundwater storage potential located below the de-watered Gravelly Ford reach of the San Joaquin. Figure 20 depicts the evolutions of the water table below the Central Valley over the first half of the 20th century based on simulations conducted by the USGS (Willamson et al. 1989). Where once groundwater flowed smoothly towards the valley outlet through the Carquinez Strait, by 1960 this surface was interrupted by numerous depressions related to the long-term imbalance between aquifer recharge and discharge. One of the most substantial depressions, located underneath the San Joaquin River downstream of metropolitan Fresno, developed in response to the elimination of seepage from the overlying San Joaquin River and the steady increase in groundwater pumping in this region. The decline was particularly acute given that the historically high seepage rate afforded by the coarse bed material in the Gravelly Ford reach was virtually eliminated by the closure of Friant Dam.

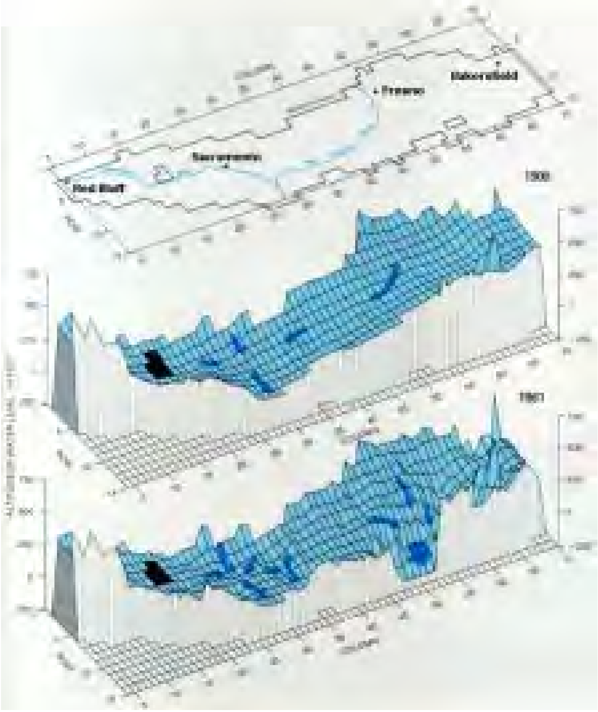


Figure 20: Water Table Evolution Below the Central Valley

There are those who discount any thought of restoring salmon to the San Joaquin precisely because of the heavy seepage losses at Gravelly Ford. They argue that the flows require to overcome these losses and to reconnect the Upper San Joaquin with the tributaries between Mendota Pool and the Delta would cripple the important agricultural economy in the southern San Joaquin Valley which rely the Friant Unit for irrigation water. Viewing the drawdown feature below Gravelly Ford as a groundwater banking site instead of as a hydrologic sink, however, provides the flexibility to restore the San Jaoquin with a minimum of disruption to the agricultural economy. This would be accomplish by re-routing water as depicted in Figure 21.

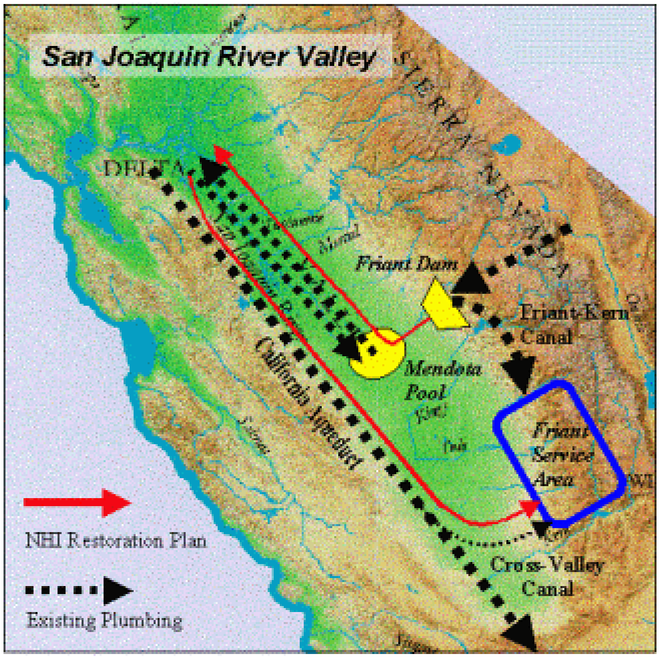


Figure 21: Proposed Arrangement for Restoring a Flow Regime in the San Joaquin River Suitable for Anadramous Fish

The basic premise of the arrangement involves wheeling Delta water currently delivered to the exchange contractors through the Delta-Mendota Canal to the southern Friant Unit via the California Aqueduct and an appropriate cross valley link. Relieving some of the demand for San Joaquin water would allow the exchange contractors to compensate for lost Delta water with releases from Millerton Reservoir. During passage over the Gravelly Ford reach, a portion of these releases would seep through the river bed and become stored in the groundwater banking site. This storage could be reclaimed by the exchange contractors should the surface water system fail to meet their demand.

In order to avoid disrupting the use of the California Aqueduct facilities by its current beneficiaries, an analysis was conducted to determine what excess capacity was available in the system between 1975 and 1996. Using monthly reports of operation for the State Water Project, the minimum capacity available to move historical deliveries from the Delta-Mendota Canal to the California Aqueduct through the O'Neill Pumping Plant and to convey these transfers through the Dos Amigos Pumping Plant was calculated. Figure 22 depicts the time series of the wheeling through the California Aqueduct which could have been accomplished using available capacity alone. This is a conservative trace as future restrictions on Delta exports may limit pumping into the California Aqueduct at Clifton Court while the exchange contractors, by virtue of their superior export right, will likely continue to have access to their 800 TAF annual allotment of Delta water delivered though the Delta-Mendota Canal.

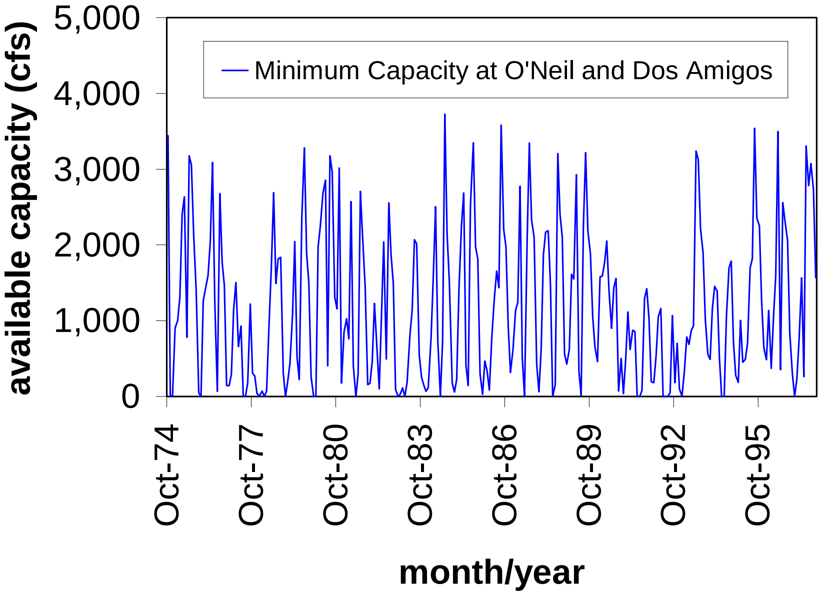
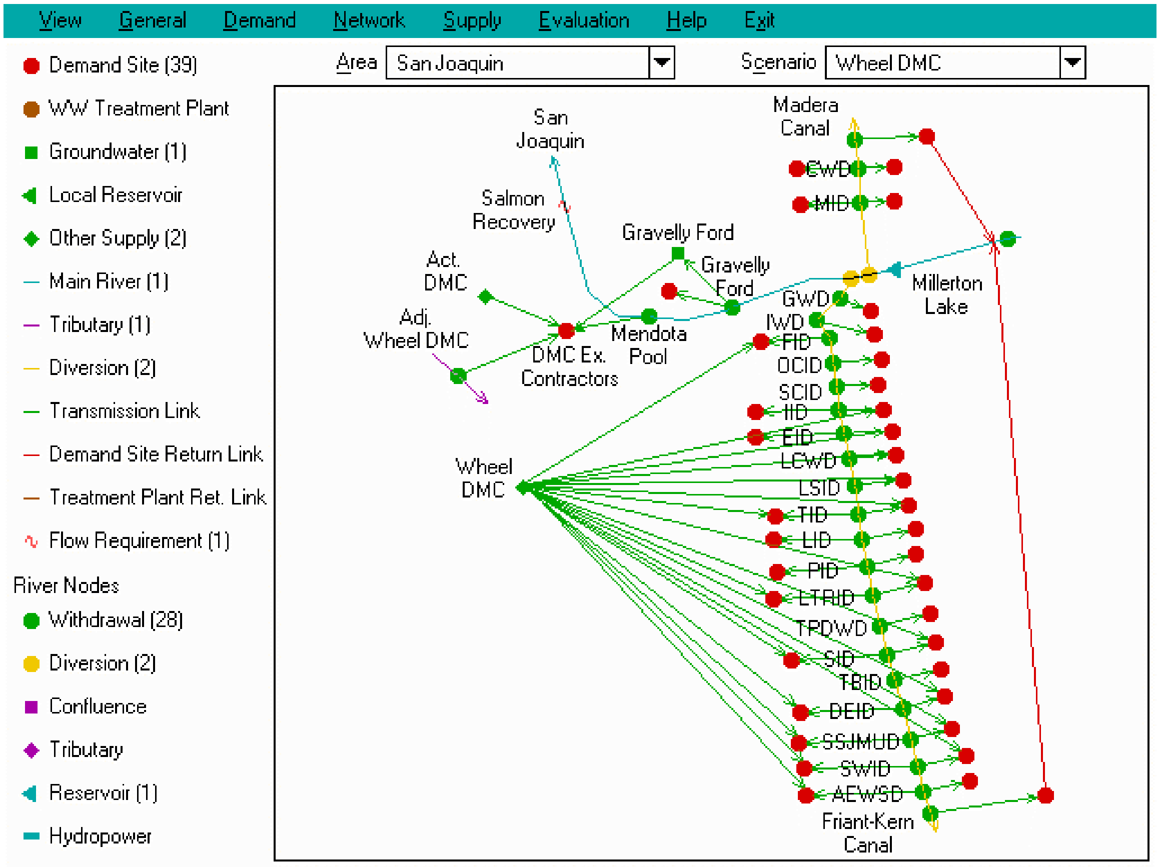


Figure 22: Historical Available Wheeling Capacity in the California Aqueduct System to a Point Below the Dos Amigos Pumping Plant.

Transfer of this Delta water into the Friant Unit could be accomplished through a variety of means. These could included the expansion of the Cross Valley Canal, the construction of some form of a Mid-Valley Canal, or institutional arrangements which would offer the wheeled water to agricultural interest in the Tulare Basin in exchange for the right to divert some of their Kings River water to the southern Friant Unit. In the context of this feasibility study, how the wheeling would be completed is of less interest then the opportunity which it would create to profit from the groundwater banking opportunity at Gravelly Ford.

The WEAP network configuration for this opportunity is presented in Figure 23. Three scenarios are simulated in this analysis. In a base case, which mimics the current arrangements, the exchange contractors receive water from the Act. DMC supply node while all other transmission links to the node are inactive. Transmission links emanating from the Wheel DMC supply node are also inactive under this scenario, as are those associated with Mendota Pool node and the Gravelly Ford groundwater banking site. In essences the exchange contractors receive their water from the Delta while the irrigation districts serviced by the Friant Unit receive water from Millerton Lake on the San Joaquin. Under a salmon recovery scenario a set of instream flows are imposed below the Mendota Pool. These standards, which were developed based on analysis by Cain (1997), are in keeping with the screening scope of this analysis.

As the analysis of this groundwater banking opportunity evolves these standards will be submitted to prominent fish biologists for review. Anticipating that the imposition of these standards will adversely impact the important agricultural interests in the Friant Unit, a final scenario integrates the Gravelly Ford groundwater banking site into the surface water system. Under these arrangements those transmission links which were inactive during the base case become active, the exchange contractors receive a smaller supply of Delta water though the Adj. Wheel DMC tributary, with the wheeled water being sent into the southern Friant Unit trough the Wheel DMC node. Groundwater is stored in the groundwater banking site both by simulated seepage in the river reach between Gravelly Ford and Mendota Pool and through intentional transfers of water from Millerton Lake to the Gravelly Ford groundwater node through the Gravelly Ford withdraw node.


Area: San Joaquin

Scenario: Wheel DMC

Figure 23: WEAP Gravelly Ford/Madera Ranch Network Configuration

In these simulations, an active salmon recovery standard is met prior to any San Joaquin River water being diverted for consumptive use. The implication of this logic is that the desired eco-system objectives will be achieved under both the salmon recovery and wheeling scenarios. What is most relevant to this analysis is the degree to which groundwater banking can mitigate any impact which existing water users would experience by virtue of losing access to the San Joaquin River water released downstream to meet the standard. Figure 24 depicts the supply requirement coverage for the Class 1 contracts of two representative water districts in the Friant Unit, the Ivanhoe Irrigation District on the Friant-Kern Canal and the Chowchilla Water District on the Madera Canal. The negative economic impacts of imposing standards would apparently be most severe during drought periods. In 1977 for example, the degree to which demand was satisfied under the base case would have been reduced by nearly 14 % because of the reduction in Millerton storage associated with downstream releases. In this simulation however, the Delta-Mendota Canal exchange contractors would have experienced no decline in their level of service as deliveries from the Delta do not change. Under wheeling arrangements on the other hand, Friant Unit districts experience less severe reductions in service relative to the base case, even with the imposition of the salmon recovery instream standard. The exchange contractors also fare well under these arrangements. In the simulation, the critically dry 1977 was difficult for both the exchange contractors, which suffered reduced Delta deliveries without being able to tap into a fully recharged groundwater bank, and the Chowchilla WD which did not have access to the wheeled DMC supply. With access to this Delta water, the Ivanhoe Irrigation District actually benefited from improved service.

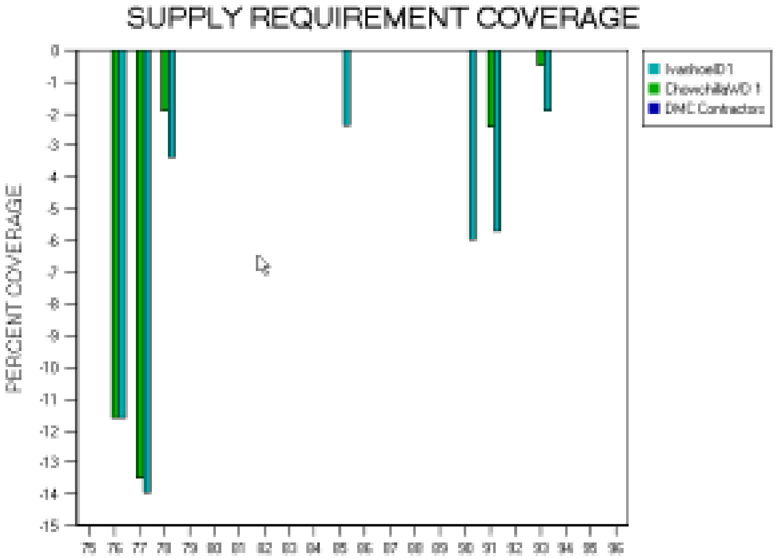


Figure 24: Change in Supply Requirement Coverage Between the Base Case and the Salmon Recovery Scenarios

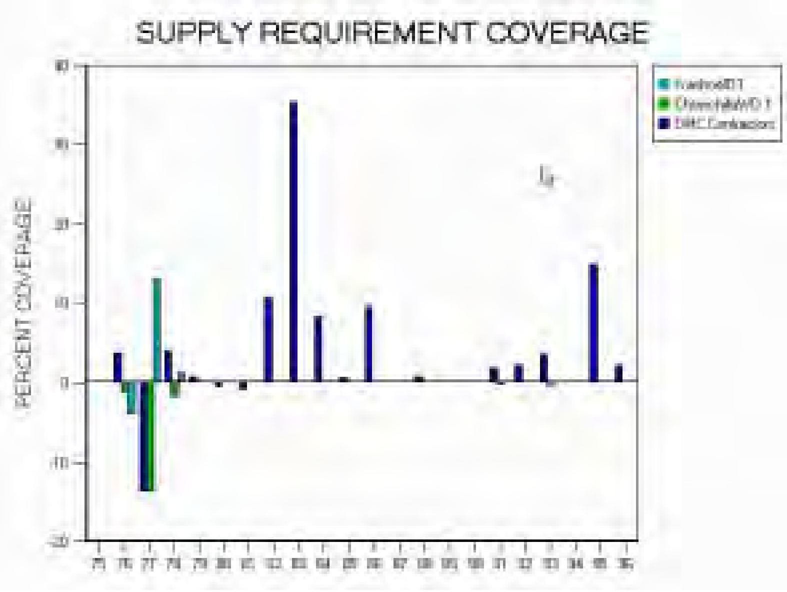


Figure 25: Change in Supply Requirement Coverage Between the Base Case and the Wheeling Scenarios

Figure 25 is a compelling example of how groundwater banking can transform potentially contentious environmental goals such as the restoration of the San Joaquin River into achievable objectives. Although water quality considerations, which could potentially prove problematic, have not been explicitly considered in this analysis, from a purely water supply perspective it appears that the salmon restoration releases can be made without overly taxing existing interests. This can occur because of the extra storage available in Gravelly Ford Groundwater Bank allows for greater flexibility in flood control operations at Millerton Lake which reduce the magnitude of the peak spill events in the San Joaquin River (Figure 26).

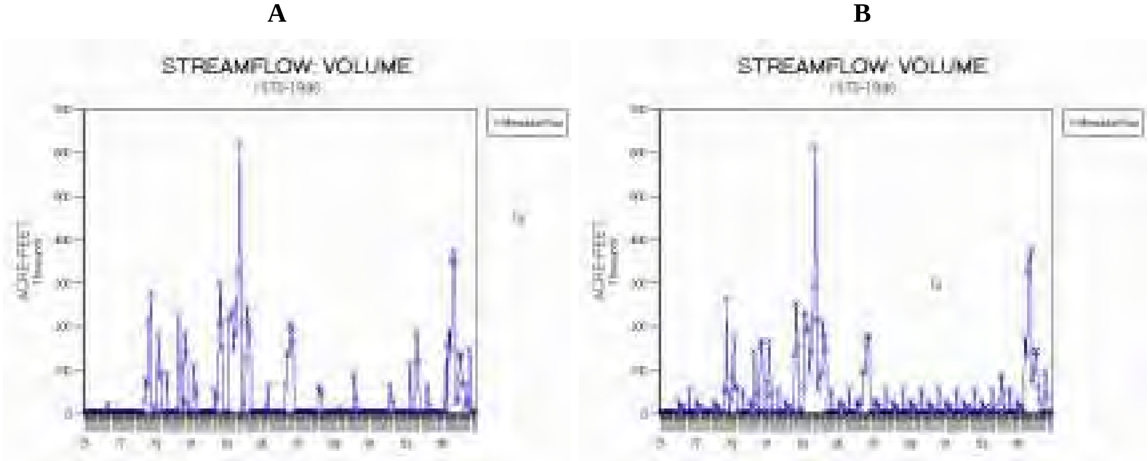
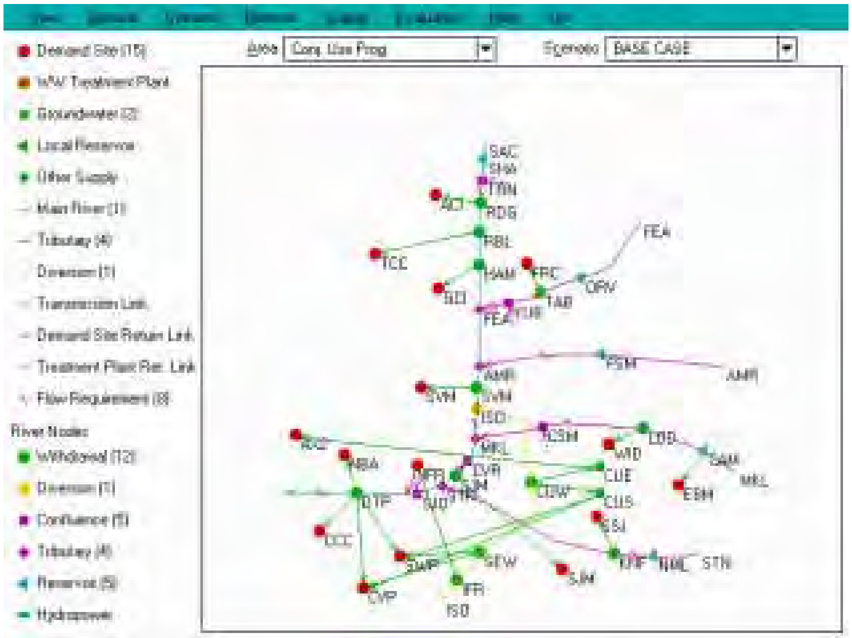


Figure 26: Simulated Streamflow Volumes in the San Joaquin River Below Mendota Pool Under the Base Case and Wheel DMC Sceanrios

The groundwater banking opportunity in Yolo County was framed as an approach for increasing both local and regional water management opportunities, while the Gravelly Ford opportunity was explored for its environmental restoration potential. By virtue of its strategic location relative to the Delta, the next suite of operational analysis highlights the real opportunity which maximal scale groundwater banking creates to achieve the full range of water supply and environmental benefits.

VI.3 Achieving Broad Benefits: East San Joaquin County

A WEAP network configuration which integrates the east San Joaquin County aquifer into the Central Valley water system is shown in Figure 27. A full a description of each of the features in the network is contained in Table 17.



Area: Conj. Use Prog
Scenario: BASE CASE

Figure 27: WEAP East San Joaquin County Network Configuration

Table 15: List of Features Included in the Case Study Network Configuration
(refers to Figure 27)

Feature Type	Name	Abbreviation
Main Stem	Sacramento River	SAC
Tributary	Feather River	FEA
	American River	AMR
	Mokelumne River	MKL
	Stanislaus River	STN
Reservoir	Lake Shasta	SHA
	Lake Oroville	ORV
	Folsom Lake	FSM
	Camanche/Pardee Reservoir System	CAM
	New Melones Reservoir	NML
Confluence	Trinity Diversions	TRN
	Yuba River	YUB
	Cosumnes River	CSM
	Calaveras River	CLV
	San Joaquin River	SJO
Active Diversion	Cross-Delta Isolated Faciity	ISO
Withdraw Node	Redding	RDG
	Red Bluff	RBL
	Hamilton City	HAM
	Thermalito Afterbay	TAB
	Sacramento Valley Municipal	SVM
	Lodi	LOD
	Knights Ferry	KNF
	Conjunctive Use	CUW
	Southern Export	SEW
	X2 from Isolated Facility	X2I
	Isolated Facility Return	IFR
	San Joaquin Valley Municipal	SJM
	Delta Pumps	DTM
	X2 from River	X2R
Conjunctive Use Node	Environmental Aquifer Storage	CUE
	Water Supply Aquifer Storage	CUS
Actual Demand Node[1]	Anderson-Cottonwood Irrigation District	ACI
	Tehama-Colusa Canal Authority	TCC
	Glenn-Colusa Irrigation District	GCI
	Feather River Canals	FRC
	Sacramento Valley Municipal	SVM
	East Bay MUD	EBM
	Woodbridge Irrigation District	WID
	South San Joaquin Irrigation District	SSJ
	San Joaquin Valley Municipal	SJM
	North Bay Aqueduct	NBA
	Contra Costa Canal	CCC
	Central Valley Project	CVP
	State Water Project	SWP
Fictitious Demand Node[2]	Isolated Facility Return Flow	IFR
	Additional X2 Water	AX2

Notes

1. An actual demand node refers to one meant to represent an actual off-stream demand site for which data on water consumption has been collected and evaluated
2. A fictitious demand site refers to a feature which has been added to “trick” the program into carrying out a water transfer not explicitly included in the allocation algorithm.

This configuration represents a large-scale view of the northern portion of the Central Valley which encapsulates two management scenarios: a base case and an enhanced Delta conveyance/ groundwater banking alternative. When the 8500 cfs ISO active diversion feature and the groundwater banking nodes are active, unallocated surface water in the Sacramento Valley is pre-delivered to a severely overdrafted groundwater banking site in eastern San Joaquin County. This water can be used to raise the level of the groundwater system during times of abundant water supply and to supplement local and south of Delta demand or enhance Delta outflow during times of shortage. When no unallocated water is available or when the groundwater banking site is full, the active diversion feature can be used to meet south of Delta demand. By shutting off the active diversion labeled ISO, all of the features which branch from the enhanced conveyance system, including the groundwater banking site and the links to the southern export demand sites are deactivated, leaving the system in roughly its current form.

The hydraulic infrastructure currently in place in California developed progressively over the course of the 20th century. By the 1970s, however, the current hydraulic infrastructure in California was largely built out. Therefore the actual flow measurements made at various points around the State during this period already reflect the modifying influence of the fully developed water system. By limiting the simulated time horizon to the period between 1970 and 1992, historical hydrologic data can be used to drive the simulation. The proposed simulated time horizon contains some of the wettest years in the historical record, the 1974 water year for example, and the strongest, 1976-1997, and longest, 1987-1992, recorded droughts in the region. The placement of the protracted drought at the end of the simulated time horizon allows for direct comparison between the current arrangements and the proposed scenario.

The California Water Plan Update (DWR, 1994) estimated that 6.0 MAF of aquifer storage capacity exists in San Joaquin County. Rather than except this extremely optimistic assessment, whose derivation is not fully explained, our analysis adopted a very conservative view on the actual storage potential present in the field. A realistic available capacity of 600 TAF was derived following close evaluation of the drawdown feature shown in Figure 28, and was allocated equally to water supply and environmental restoration storage.

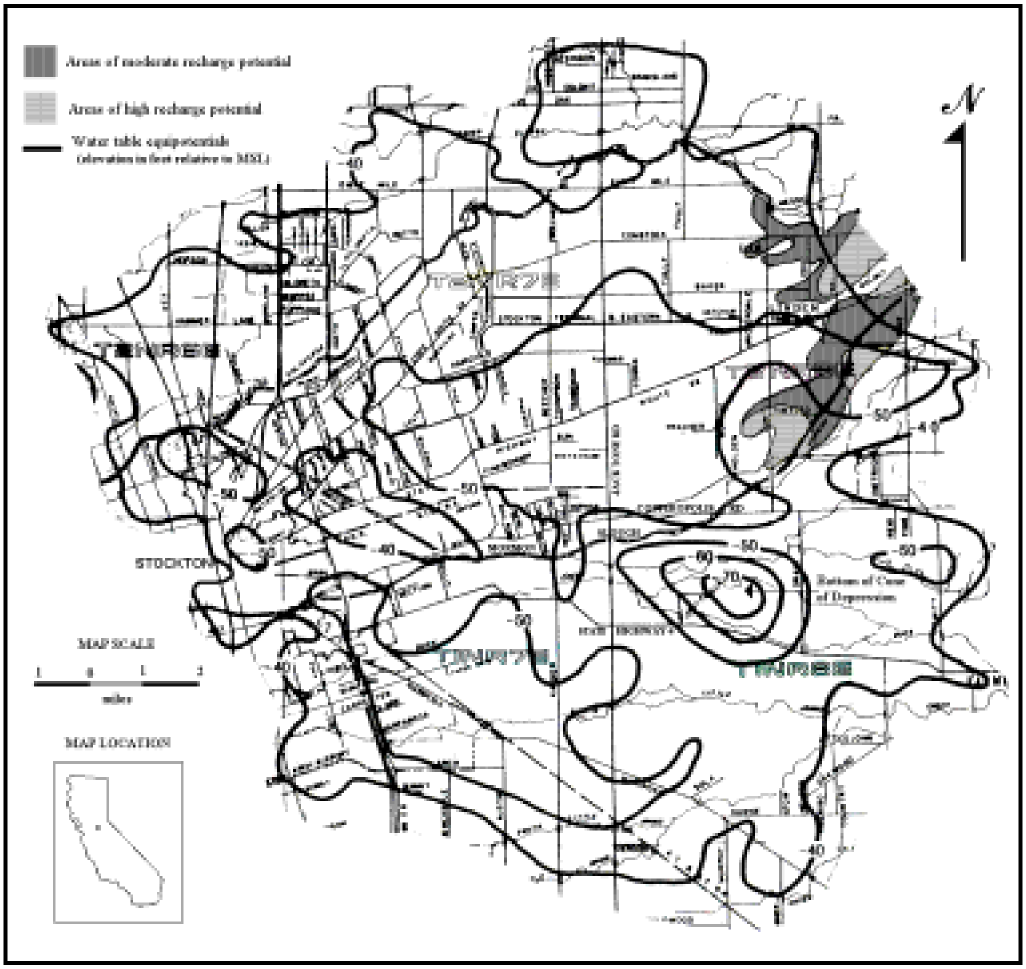


Figure 28: Spring 1995 Water Table Elevation Map East of Stockton, California

One basic result of the simulation has to do with the degree to which the enhanced Delta conveyance/ groundwater banking alternative improves the ability to deliver water to points of demand which can be supplemented by tapping storage in the groundwater bank. These include the SWP and CVP actual demand sites which access water supply storage and the Additional X2 demand which accesses environmental storage. The water supply benefit is seen clearly in Figures 29 and 30 which depict the temporal pattern of deliveries to the SWP and CVP nodes respectively. Under the proposed alternative, during 1977, surface water deliveries through the Delta pumps under the Base Case are largely replace by surface deliveries through the Isolated Facility with supplemental water being drawn from aquifer storage to help make up the simulated shortfall (Figures 29B and 30B). During 1988, the decrease in surface storage means that little or not deliveries of surface water take place under the proposed alternative, either through the Delta pumps of the Isolated Facility. In the extreme case, July 1988, the only water going to meet supply is from aquifer storage (Figures 29C and 30C). It seems likely that the generally poorer performance of the CVP relative to the SWP is related to the smaller amount of transmission capacity dedicated to the Federal project in the Isolated Facility and in the links issuing from the aquifer storage site. The results would have been different had the percent participation of the State and Federal projects been reversed. Adjusting the distribution of capacity is the type of screening exercise to which WEAP is ideally suited.

Figure 31A depicts the total Delta outflow in the Base Case and under the enhanced Delta conveyance/ groundwater banking alternative. Under the proposed alternative Delta outflow is the sum of the simulated flow at the bottom of the river system and the transfer from aquifer storage to the Additional X2 node. The curves reveal that in extremely wet years, outflow in is higher in the Base Case, presumably because some of the excess water is being transferred to aquifer storage. In the driest years, on the other hand, the proposed alternative offers a small supplement over and above the minimum standards which have been imposed. This is a logical result. It also seems reasonable that the Export:Import regime in the Delta improved under the proposed scenario (Figure 31B). In dry years water is delivered for southern export primarily through the Isolated Facility prior to entering the Delta. In this case the ratio of southern export to Delta inflows drops to nearly zero.

On balance, the results of this simulation reinforce the notion that the proposed alternative could improve the performance of the Central Valley water system. What is particularly attractive about this specific opportunity is how it could help both local and regional water managers to respond to both water supply and environmental challenges. Located as it is at the nexus of the Central Valley water system, the east San Joaquin County groundwater banking site offers flexibility which may be unparalleled in California. The staggering effects of the dewatered local aquifer also provide enormous potential for collateral local benefit in terms of reducing energy expenditures for pumping and protecting the water quality of one of the States important metropolitan centers. All of the actors, both locally and regionally, should be assembled to further investigate how this potential benefit of this site could be realized.

VI.4 Concluding Thoughts

The three preceding examples of operational analysis clearly demonstrate the array of issues which must be addressed in working out the operational details of a specific groundwater banking opportunity, and the enormous benefit which can be gained in so doing. These examples also demonstrate the utility of the WEAP model for exploring the site specific nuances of these opportunities. Developing WEAP network configurations for the other potential sites will be a major focus of future work on this project. These models will allow for an exploration, in concert with all interested actors, of the implications of site specific management decisions. NHI is convinced that this dialogue will allow the most promising sites to emerge from the pack, so to speak, so that further requisite analysis using DRWSim and other suitable tools can proceed apace.

Figure 29: Deliveries to the SWP Demand Node for the Base Case (red) and Isolated Facility/1.2 MAF Conjunctive Use Alternative (green)
A: Over the Entire Simulated Time Horizon; B: During the 1977-1978 Drought; and C: During the 1987-1992 Drought
(heavy solid line: total deliveries; light solid line: Delta pumping; short dashed line: Isolated Facility; long dashed line: aquifer storage)

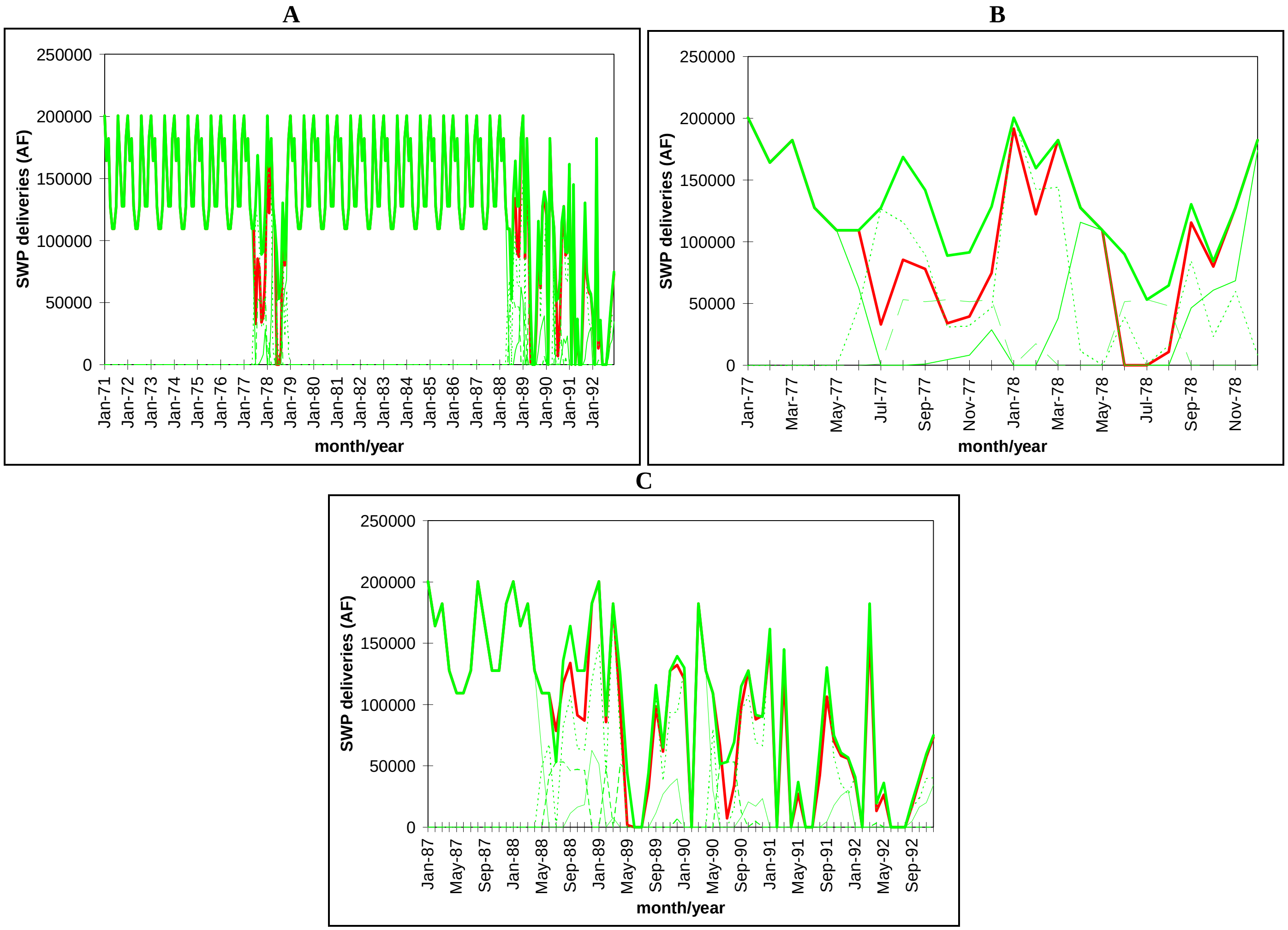


Figure 30: Deliveries to the CVP Demand Node for the Base Case (red) and Isolated Facility/1.2 MAF Conjunctive Use Alternative (green)
A: Over the Entire Simulated Time Horizon; B: During the 1977-1978 Drought; and C: During the 1987-1992 Drought
(heavy solid line: total deliveries; light solid line: Delta pumping; short dashed line: Isolated Facility; long dashed line: aquifer storage)

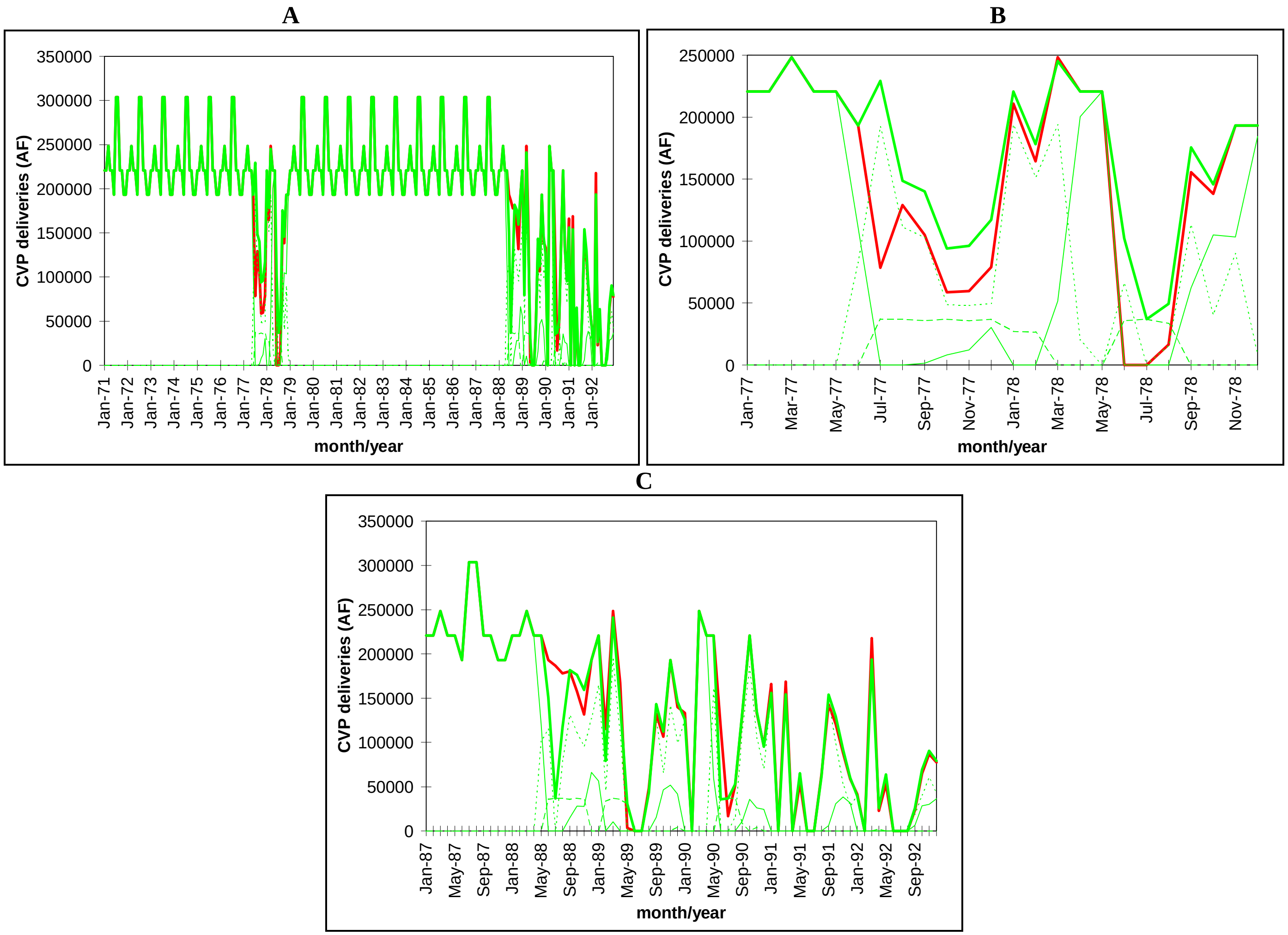
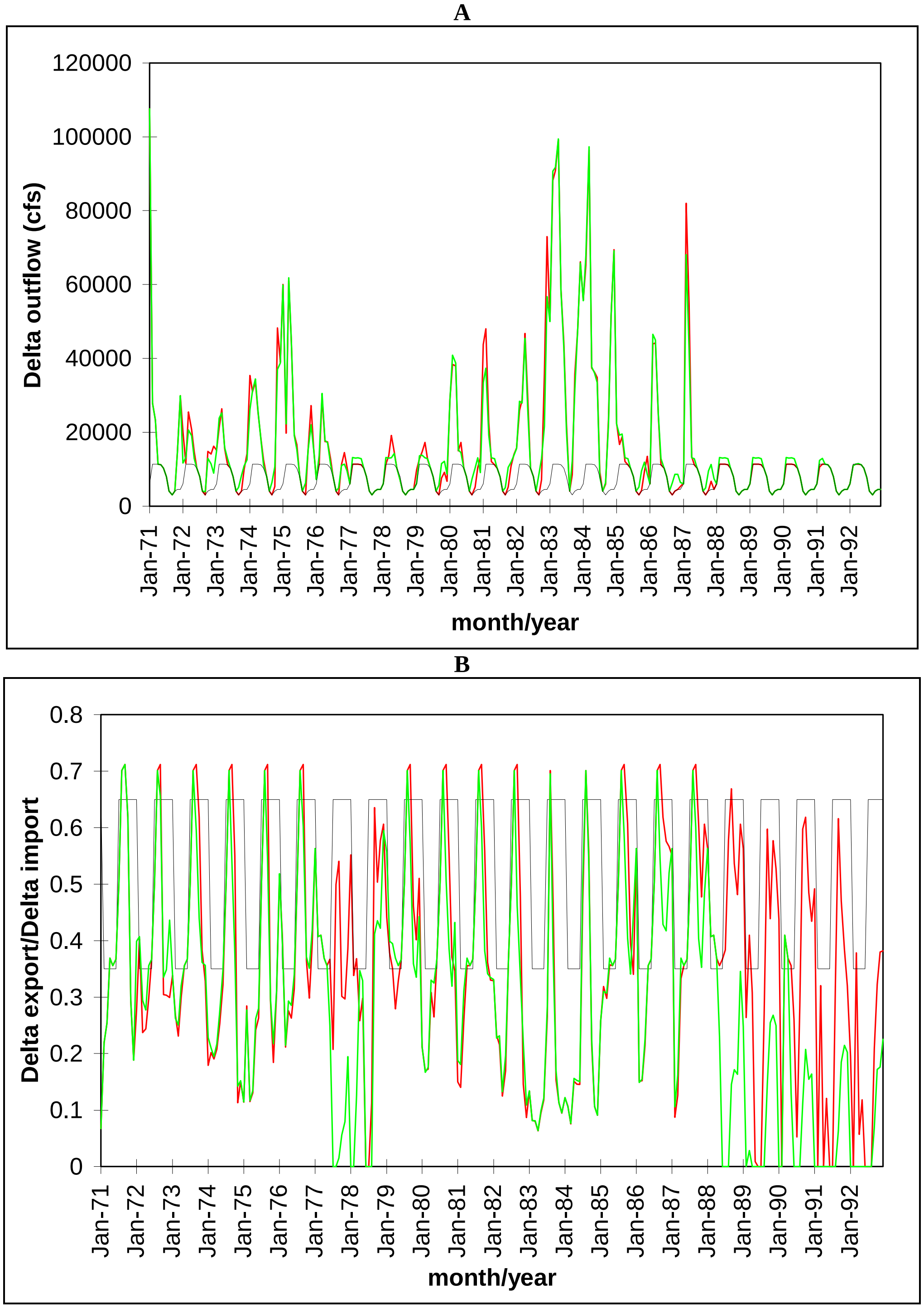


Figure 31: Simulated Delta Flow Regimes A: Delta Outflow and B: Export/Import Ratio for the Base Case (red) and the Isolated Facility/Conjunctive Use Alternative (green) as Compared to the Standard (black)



VII. Workplan Step 5: Economic Analysis

The economics of groundwater banking are often difficult to estimate and highly dependent on the specific characteristics of a given project. Recharge and extraction costs vary depending on aquifer characteristics and the nature of existing facilities. Greater uncertainties arise from the potential for unanticipated costs due to third party or environmental impacts. These can arise both in the source and recharge areas. Benefits are also variable. They range from the easily quantified savings associated with lower pumping lifts to the less easily quantified benefits associated with the insurance value of secure supplies. As with costs, many of these benefits depend on site characteristics.

VII.1 Direct Costs

Recharge and extraction costs in current projects range from a low roughly $20 to over $300 per acre-foot (Appendix V). Typical cost ranges for new projects estimated in the context of the CVPIA are $90-120/acre-foot at the source (USDOI, USBR et al. 1995). These costs do not, however, include any charges for the water being supplied. Districts in MWD's service area would, for example, need to pay its charges for replenishment water on top of their actual costs for recharge and extraction. Where in-lieu methods of recharge are possible using existing facilities, recharge costs can be extremely low. On the Conway ranch in Yolo County and in parts of Kern county they can be as little as $5/acre-foot.[36]

The direct costs indicated above and in Appendix V may, however, be misleading for conjunctive management activities in the future. As MWD notes in its recent IRP document: "A significant problem with groundwater conjunctive use storage is getting the water into the basin." (MWD 1996). This constraint is noted as a significant justification for their major Eastside Reservoir Project which could be used to temporarily store water during periods when existing recharge facilities are operating at capacity. The cost of this facility is estimated to be $1.9 billion.

VII.2 Benefits

Previous analyses of groundwater banking economics have focused primarily on the value of groundwater management activities within a limited agricultural area (e.g. Knapp and Olson 1995). Groundwater banking is modeled not as a way of creating "new" water supplies that would be available for any use, but more as a way of changing the cost structure of supplying a given amount of water to existing -- generally agricultural -- uses. As a result, the benefits are determined primarily by changes in the pumping costs versus management investments to supply that water. In contrast, this paper views the economics of groundwater banking from the perspective of storage creation. Groundwater banking use is a way of increasing the reliability of existing supplies and capturing new supplies that would otherwise be unavailable to the system as a whole through the creation of groundwater reservoir storage facilities. The economics of groundwater banking must therefore be analyzed in the same manner as surface storage reservoirs or other mechanisms for generating new or more reliable yield within an existing system.

While a full economic analysis of the benefits from groundwater banking is beyond the scope of this paper, it is important to note that the benefits associated with groundwater banking are not fully captured by analysis of new yield options on a least-cost of average annual supply basis. Three factors seem particularly important to note: (1) the stabilizing role of groundwater supplies; (2) the insurance value associated with ability to pre-deliver supplies; and (3) relative insensitivity of groundwater banking projects to changes in key economic assumptions.

In any situation where surface water supplies are variable, the presence of groundwater resources that can be tapped "as needed" for municipal, agricultural or other uses carries a stabilization value beyond that associated with increases in water supply alone. In an analysis of wheat cropping in the Negev desert,

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[36] DWR, 1994, SWP Conjunctive Use--Eastern Yolo County; Kern County CA. April 1995. 1995 KFE Property Recharge Program.

Tsur estimated the stabilization value of groundwater development as "more than twice the benefit due to the increase in water supply."(Tsur 1990). In Southern California where surface water supplies are less variable than the Negev, the stabilization value in agriculture is, in some cases, as much as 50% of the total value of groundwater (Tsur 1993). Crop yield responses are often dependent on the timing of water application as well as the volumes delivered. Since water stored in a groundwater banking site and dedicated for agricultural use will often be close to the point of end-use (e.g. on overlying lands), users will be far more able to fine tune extraction to meet their needs than they would be if they depended primarily on supplies stored in distant reservoirs. Groundwater banking operations will, thus, enhance the ability of groundwater resources to play a stabilization role. Furthermore, developing groundwater banking operations in areas currently dependent primarily on surface water would give those areas direct access to new "stabilization" benefits. In an analysis of groundwater banking in the South Platte system in Colorado, Bredehoeft and Young found that *installing sufficient groundwater pumping capacity to provide water to all areas irrigated by surface supplies made economic sense*. Doing this maximized expected net benefits and minimize annual income variation (Bredehoeft and Young 1983). As Tsur notes, ignoring the stabilization value of groundwater in economic comparisons with surface supplies, can seriously bias policy making based on cost-benefit considerations (Tsur 1993).

Municipal users also place a premium on supply stability. A recent contingent valuation survey found that: "on average California residents are willing to pay $12 to $17 more per month per household on their water bills to avoid the kinds of water shortages which they or their regional neighbors have incurred in recent memory. The statewide magnitude of such additional consumer payments would be well over $1 billion per year." (Barakat & Chamberlin 1994). The lower figure represents a 20% shortage every 30 years while the higher applies to a 50% shortage every 20 years. Residents are also willing to pay between $11.67/month and $12.14/month to avoid shortages of 10% occurring with a frequency of 10 and 3 years respectively.

Insurance values associated with groundwater banking are closely related to stabilization. The distinction between stabilizing natural fluctuations in water availability and insurance against major disruptions is important. Elements of California's surface water supply system are highly vulnerable to earthquakes. Other sudden events -- for example, major pollution spills -- could also disrupt water supplies over short to medium term periods. The economic costs of these disruptions could be major for any of the industrial, agricultural, municipal or environmental users. Groundwater banking operations, by pre-delivering water to locations nearer to points of end-use and storing it in underground reservoirs that are relatively invulnerable to sudden disruption, will provide major insurance benefits.

Another economic benefit of conjunctive use in comparison to most water supply projects is relative insensitivity to discount rate and other development cost assumptions. Unlike surface supply, most conjunctive use projects can be completed rapidly or brought on-line sequentially as components are completed. They often do not have the long gestation periods and high up-front capital costs associated, for example, with the construction of a new reservoir. Furthermore, the benefits associated with individual components, such as spreading basins, can be realized even if a system is only partially completed. They do not depend on completion of an entire system. As a result, the economic viability of conjunctive use does not depend to the same degree as large surface projects on accurate projections of economic and other parameters (such as population growth) into the future. This benefit will, of course, only be true to the extent that groundwater banking projects are not dependent on the construction of major new surface facilities.

The stabilization and insurance values of water stored underground and the relative insensitivity to economic assumptions of conjunctive use projects are not captured in least-cost comparisons of yield generated. Estimating these and incorporating them into the economic evaluation will be important to evaluate the true costs and benefits of conjunctive use.

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Appendix I: Limnological Context for Reservoir Stratification

In a barotropic water body, the fluid density remains invariant with depth. This is somewhat of a hypothetical state which would be difficult to establish and maintain in a natural system. Many factors leading to the establishment of vertical density gradients, so called baroclinic conditions, act upon lakes in nature. In the context of a maximal groundwater banking program, the most important is the input of solar radiation at the water surface. Workplan Step I describes how reservoir re-operation would increase yield in the Central Valley water system via the transfer of surface water to aquifer storage in advance of winter storms. In the event of a wet winter, the excess reservoir capacity would be used to retain runoff normally released as part of flood control operations. A dry winter, on the other hand, might leave the reservoirs drawn down to a point where the input of solar radiation might subsequently make it difficult to maintain downstream temperature regimes suitable for aquatic resources, primarily anadromous fish.

As solar radiation penetrates into a lake or reservoir, it is absorbed at an exponential rate. Figure AI.1 shows how far into a body of distilled water two different wavelengths of visible light penetrate.

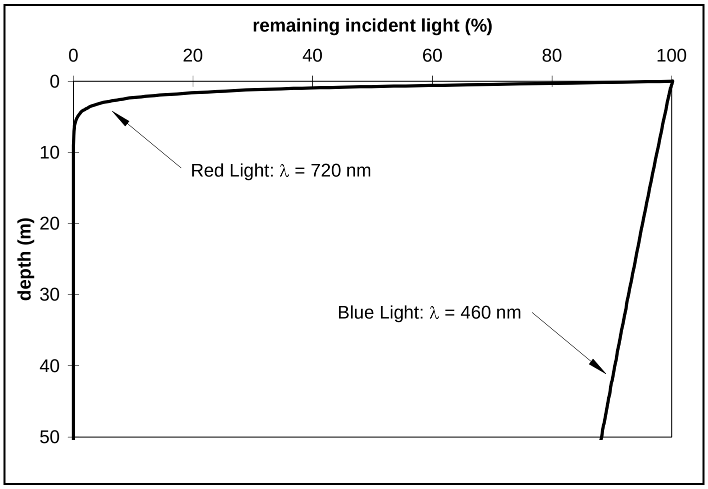


Figure AI.1: Light Penetration into Distilled Water for Red and Blue Regions of the Visible Light Spectrum
(source: Cole 1983)

According to these curves, by a depth of 5m, all but 1% percent of the incident red light (λ=720 nm) has is absorbed by the water and converted to thermal energy. A similar pattern exists for infrared radiation which lies just outside of the visible portion of the spectrum. Shorter wavelength blue light (λ=460 nm), on the other hand, remains relatively unabsorbed even at depth of 50 m. Since it is the red/infrared wavelengths which convert much of their energy to heat when absorbed, the most intense warming takes place in top several meters of the water column.

If the input of solar radiation occurred in an initially isothermal lake, the resulting temperature profile would resemble the red/infrared penetration profile (Figure AI.2A). Under these conditions additional inputs of radiation would generate downward heat flow driven by temperature gradients. In addition to this driving force, however, the lake is exposed to winds passing over its surface. This wind serves to mix the water near the surface of the lake distributing the heat more evenly within the zone of mixing (Figure AI.2B). The end result is a layer of warmer, less dense water which overlies colder heavier water below. Additional inputs of solar energy and further wind-driven mixing will continue to warm the surface layer making it increasing less dense relative to the cold layer below. The lake has become *stratified*, a common occurrence during the summer months in deep lakes located in temperate regions.

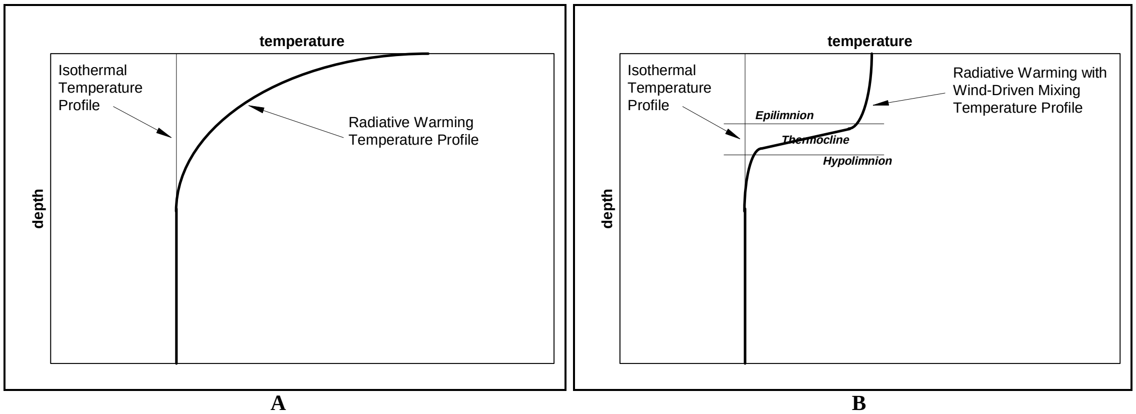


Figure AI.2: Hypothetical Vertical Temperature Profiles Assuming A: Simple Radiative Warming; and B: Combined Radiative Warming and Wind-Driven Mixing
(source: Laska 1981)

The thickness of the upper layer, or the *epilimnion*, is a function of the physio-chemical properties of the water in the lake and the dynamic interaction between the temporal pattern of incoming solar radiation and the local wind regime. It should be pointed out that the same amount of thermal energy can lead to the conditions shown in Figures AI.2A and AI.2B. If so, the integral of temperature with depth must be the same for both profiles. As the uniformly cold regions of each curve, referred to as the *hypolimnion* of the lake, are identical, the only way to preserve this equality is for a region of rapid temperature drop, or a *thermocline*, to become established between the two layers. The sharp temperature, and hence density, contrast means that in a *stratified* lake the epilimnion and the hypolimnion essentially act as separate bodies of fluid until sufficient work can be done on the system to remix them.

Actual temperature profiles taken at Lake Shasta during the month of September, Figure AI.3, reveal that stratified conditions do develop in the reservoir. Stratification seems to be most pronounced in years where the lake stage was relatively low in the late summer, as in 1961, 1964, and 1968. Data also suggest that the thermocline deteriorates with the advancing autumn. Figures AI.4A and AI.4B depict the evolution of the 1968 temperature profile in Shasta and Whiskeytown Lakes between September and November. Presumably the acceleration of radiative cooling and the inflow of cooler water with the onset of winter storms are responsible for the general cooling down of these lakes late in the fall.

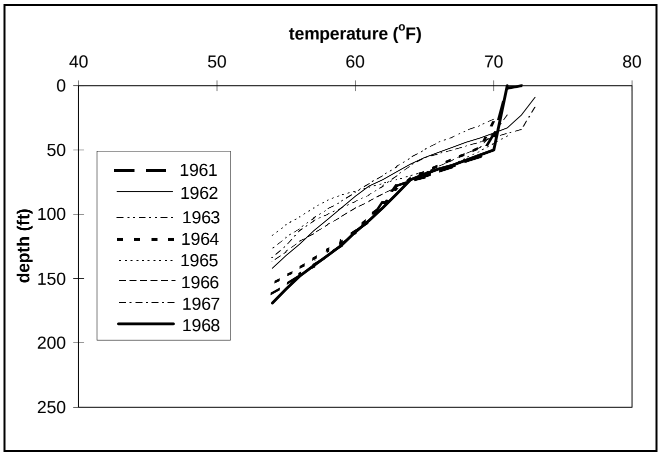
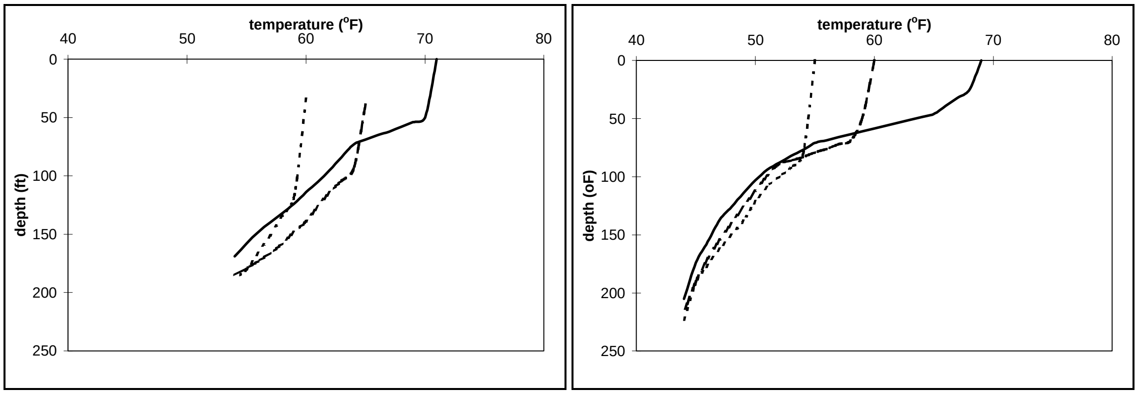


Figure AI.3: September Temperature Profiles in Lake Shasta
(bold curves represent years of low reservoir stage)
(source: Weidlein 1971)



A **B**

Figure AI.4: Evolution of Autumn, 1968 Water Temperature Profiles in A; Lake Shasta; and B: Wiskeytown Lake
(September: solid line; October: long dashed line; November: short dashed line)
(source: Weidlein 1971)

One conclusion which can be drawn from Figures AI.3 and AI.4 is that water temperatures in the epilimnion of these reservoirs are substantially higher than the 56^{o}F recommended in the AFRP for the protection and restoration of anadromous fish in the Sacramento River, particularly in September. This has profound implication for the operation of reservoirs as part of the proposed groundwater banking program. To insure that only cold water from the hypolimnion will flow into the river downstream, reservoir releases must be made from depths below the thermocline. Unfortunately, under the worst case scenario of a critically dry winter following the ambitious pre-delivery of water to aquifer storage, the thermocline may be dangerously close to the level of the reservoir release works. In this case the flow hydraulics in the vicinity of the intake may lead to the release of warm water from the epilimnion. Of particular concern in this context are internal waves in the body of the reservoir, or *seiches*, which can cause the thermocline to oscillate and may, under drawn down conditions, result in periods of time when cold water is completely absent from the vicinity of the reservoir release works. The equations governing this phenomenon are presented in the following Appendix.

Appendix II: The Initiation and Magnitude of *Seiche* Oscillations

AII.1 Wind Driven Set-Up

As the wind passes over a reach of open water it imposes a shear stress proportional to the square of the wind speed and the density of the atmosphere. This relationship is defined as:

$$\tau_S = C\rho_a W^2 \qquad \text{(AII.1)}$$

where τ_S is the shear stress; ρ_a is the density of the atmosphere immediately above the lake surface; W is the wind speed and C is an empirical parameter known as the drag coefficient. The imposition of this shear stress acts to pile up the lake surface at the offshore end thereby generating a head gradient along a line parallel to the wind direction. Theory holds that at steady state this head gradient is balanced by the opposing shear stresses acting on the lake surface and along the lake bottom.

$$\tau_S - \tau_B = \rho g i H \qquad \text{(AII.2)}$$

where τ_B is the shear stress acting along the bottom of the lake; g is gravitational acceleration; i is the angle of denivelation of the lake surface; and H is the static depth of the lake. When lake currents are turbulent, the shear stress at the surface is generally considered to be significantly larger than those acting on the lake bottom so that the ϑ_B parameter can be ignored.

Making this assumption, one can equate equations AII.1 and AII.2 and solve for the angle of denivelation under a given wind regime:

$$i = C\frac{\rho_a}{\rho}\frac{W^2}{gH} \qquad \text{(AII.3)}$$

When combined with a parameter describing the length of the lake, equation AII.3 can be used to determine the magnitude of the wind driven set-up:

$$\zeta' = \frac{iL}{2} \qquad \text{(AII.4)}$$

where ζ' is the set-up, or lake surface displacement, at the off-shore end; and L is the length of the lake. During this investigation, to solve equation AII.4, the drag coefficient was set equal to $2.3\text{x}10^{-3}$ and the density of the atmosphere to $1.25\text{x}10^{-3}$ gm/cm^3.

AII.2 *Seiche* Oscillation

Stratified lakes are not static features in which a warm layer rest motionless upon a static pool of cold water. It has long been recognized that the interface between the two bodies of water in stratified lakes, the thermocline, oscillates (Wedderburn, 1909). This oscillation is often uninodal around some central point in the lake with the end effect being that when the thermocline is elevated relative to it static level at one end of the lake, it is depressed at the other.

When a dry rainy season follows pre-delivery to aquifer storage, there is an increased risk that these oscillations, or *seiches*, will periodically place warm water in close proximity to the reservoir release works thereby displacing the cold water which would have been present under static conditions. This displacement could compromise the ability to maintain suitable temperature regimes downstream. Obviously *seiches* are complex hydrodynamic features whose properties depend on multiple variables. Nonetheless, by making some simple assumptions about the system, it is possible to develop some rules of thumb about the amplitude of these oscillations which might guide the establishment of suitable reservoir carryover storage parameters for the Central Valley reservoirs.

Consider a lake of length L and width W, where L>>W. Assume the lake is stratified into an upper warm layer of thickness h' and density ρ' and a lower cold layer of thickness h and density ρ. Once oscillation is initiated, the divergence of the lake surface and the thermocline from their static levels are represented by ζ' (the wind driven set-up in equation AII.4) and ζ respectively. As the lake is much longer than it is wide, one can assume that the oscillation is largely confined to the long, or x axis, of the lake. Manipulation of the equations of continuity and momentum for this simplified system lead to the following definition of the amplitude of the internal oscillation:

$$\zeta = -\zeta' \frac{\rho}{\rho - \rho'}\left(1 + \frac{h'}{h}\right) \qquad \text{(AII.5)}$$

Equation AII.5 suggests the following interactions between the displacement of the water surface and the displacement of the thermocline at depth:

- For a given water surface displacement, ζ', and for a given set of static eplimnoin and hypolimnion thickness values, h' and h, the internal displacement of the thermocline is inversely proportional to the density contrast between the warm and cold water pools; and
- For a given water surface displacement, ζ', and for a given density contrast between the warm and cold water pools, the internal displacement of the thermocline is proportional to the relative thickness of the epilimnion.

The combined effect of these interactions is that in stratified lakes a set-up on the order of centimeters can generate *seiche* displacements on the order of meters.

AII.3 Juxtaposition of Warm Water and Reservoir Release Works

Using the data presented in the previous sections, it is possible to approximate the magnitude of the wind driven set-up in each of the major foothill reservoirs (equation A.II.4) and the maximum displacement of warm water in the epilimnion below the static thermocline elevation during seiche-like oscillations (equation A.II.5). Having estimated the potential magnitude of displacement, the difference between the minimum elevation of the warm water in the reservoir and the elevation of the intake to the reservoir release works can be established for a given reservoir storage condition according to:

$$HT = \left(E_{surf} - D_{thermo} - \zeta\right) - E_{releases} \qquad \text{(AII.6)}$$

where: HT is the minimum hypolimnion thickness lying above the release works; E_{surf} is the lake surface elevation associate with the assumed reservoir storage level; D_{thermo} is the observed depth of the thermocline below the lake surface; and $E_{release}$ is the elevation of the release works.

Appendix III: Survey of District Recharge Activities

District	Storage Potentially Available	Current annual operating potential	Average current recharge volume
Arcade WD[37]			17,960 AF
Yuba Co. WA[38]	1,710,000		
DWR - M&T Chico Ranch[39]			12,000 AF
Western Canal Water District[40]	4,000,000 AF - total groundwater basin storage		
DWR - American Basin[41]			
DWR - Eastern Yolo County[42]			19,000 AF[43]
Alameda County WD[44]	20-32,000 AF		28,900 AF
Alameda Co. Flood Control District #7[45]	250,000 AF		10,000 AF
East Bay MUD[46]	600,000-700,000 AF	200,000 AF[47]	feasibility stage
Santa Clara Valley WD[48]		400,000 AF[49]	150,000 - 210,000 AF max Average year 100,000
Stockton-East WD[50]			5,800 AF
Chowchilla WD[51]	75,000 AF		30,000 AF

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[37] CH2MHILL prepared for Arcade Water District. November 1993. Groundwater Recharge Project Feasibility Report. Arcade WD is in the process of implementing a combination injection and in-lieu recharge program. Figures were calculated using Arcade's recommended project which injects 9896 AF/yr and purchases 7.2 mgd of surface water from the City of Sacramento and delivered as in-lieu recharge. 7.2 mgd * 365 = 2,628 g/year. 2,628 g/year = 8,064 AF/yr in-lieu (1 AF = 325,900 g). 9,896 injection + 8,064 in-lieu = 17,960 AF/yr. This program, however, has not yet been implemented.

[38] Yuba County WA. September 1992. Ground Water Resources and Management in Yuba County. Figure is total storage capacity, it would not be feasible to include this amount of water in a conjunctive use program. Calaculated within the Yuba Co. groundwater study area which includes 49,800 acres in Yuba-North subarea and 88,700 acres in Yuba-South subarea to a depth of 200 feet.

[39] CH2MHILL. November 1994. DRAFT Conjunctive Use Working Paper Water Augmentation Program.

[40] Brown, G., Western Canal Water District. June 19,1995. Personal Communication.

[41] DWR, 1995, American Basin Conjunctive Use Project, Pre-Feasibility Report, California Department of Water Resources, Sacramento, pp 138.

[42] DWR, 1994, SWP Conjunctive Use--Eastern Yolo County, Draft Pre-Feasibility Report, California Department of Water Resources, Sacramento.

[43] In-delivery occurs during wet years, therefore, pre-feasibility report estimate indicates this amount of recharge would occur every other year.

[44] Halliwell, M., Alameda County WD. August 15, 1995. Personal Communication. 28,900 AF were recharged in 1993-94 water year due to an excess amount of water being discharged, forecasted recharge volume 1994-95 is 21,100 AF. Alameda County Water District. February 1995. Survey Report on Groundwater Conditions.

[45] Chahal, J., Alameda Co. FCD and WCD #7. July 17, 1995. Personal Communication.

[46] EDAW, Inc. December 1992. Draft EIS/EIR for the Updated Water Supply Management Program. Prepared for East Bay Municipal Utility District, Oakland, California.

[47] Potential annual withdrawal for conjunctive use if the program incorporated 100 wells with an average production capacity of 1200 gpm

[48] CH2MHILL draft report. estimate pending information from district.

[49] Personal Communication, William Molnar, Water Resource Development Division

[50] Thomas, J., Stockton-East WD. July 1995. Personal communication. District is currently searching for additional percolation sites to increase their annual recharge rate, and reduce overdraft.

[51] CH2M HILL. 1994. DRAFT Conjunctive Use Working Paper.

Rosedale RioBravo WD		209,950 AF[52]	89,385 AF[53]
Kern Delta WD		76,740 AF[54]	3,874 AF[55]
Buena Vista WSD		372,843 AF[56]	30,732 AF[57]
Tranquility WD[58]			At reconnaissance level which may evolve into a project (2-3 years) storage account 5,000 AF
Kern Water Bank[59]			Project on hold pending habitat conservation plan - previously recharging 100,000 AF annually
City of Fresno[60]			> 50,000 AF
Fresno ID[61]			60,000 AF
Laton CSD[62]			117 AF
Liberty WD[63]			15,000 AF
Westlands[64]			No formal recharge project, individual growers bank water
Arvin-Edison WSD		108,595 AF[65]	122,917 AF[66]
City of Bakersfield		180,992 AF[67]	7,881 AF[68]
Semitropic WSD, Groundwater Banking Project with MWD[69]	Roughly 1,000,000 acre-feet total available.	"put" max 315,000 AF/yr, "Take" max 224,000; guaranteed put of 91,000; guaranteed take of 90,000.	
Semitropic/MWDSC Water Storage and Exchange Program		31,500 - 170,000 AF[70]	

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[52] Figure is calculated using the recharge rate (cfs) for facilities within the district, therefore it is the highest possible number using existing facilities and assuming water is available year round. Kern County Water Agency.

[53] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[54] Figure is calculated using the recharge rate (cfs) for facilities within the district, therefore it is the highest possible number using existing facilities and assuming water is available year round. Kern County Water Agency.

[55] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[56] Figure is calculated using the recharge rate (cfs) for facilities within the district, therefore it is the highest possible number using existing facilities and assuming water is available year round. Kern County Water Agency.

[57] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[58] Brian Ehlers of Provost and Pritchers. June 16, 1995. Personal Communication.

[59] Arvey Swanson, DWR. July 21, 1995. Personal Communication. CH2MHILL 1994. DRAFT Conjunctive Use Working Paper.

[60] Integrated Water Technologies, Inc. June 1995. Presented at ACWA Groundwater Mini-Conference.

[61] Bettner, T., Fresno ID. July 1995. Personal Communication.

[62] Buttle, R., Laton CSD. July 1995. Natural Heritage Institute survey results. Substantial annual variation, depending on hydrologic conditions in the Sierras, range is from 0 - 15,000 AF.

[63] Liberty WD. July 1995. Natural Heritage Institute survey results.

[64] Dave Sunding. August 15, 1995. Personal Communication.

[65] Figure is calculated using the recharge rate (cfs) for facilities within the district, therefore it is the highest possible number using existing facilities and assuming water is available year round. Kern County Water Agency. Kern County Water Agency.

[66] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[67] Figure is calculated using the recharge rate (cfs) for facilities within the district, therefore it is the highest possible number using existing facilities and assuming water is available year round. Kern County Water Agency. Kern County Water Agency.

[68] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[69] Semitropic Water Storage District and Metropolitan Water District of Southern California (1994) Semitropic Groundwater Banking Project, Final EIR, July 1994, p. 5-197.

[70] Metropolitan Water District of Southern California. July 1995. Regional Urban Water Management Plan for MWDSC, p. 109. Under the joint program, MWDSC will have the right to store up to 350,000 AF. Semitropic provides Metropolitan with access to existing and new facilities and provides other necessary services for storage and recovery of SWP or other water supplies. MWDSC pays Semitropic for water management services.

I.D. No. 4 (Kern County)		296,102 AF[71]	82,960 AF[72]
Wheeler Ridge-Maricopa WSD			6,882 AF[73]
North Kern WSD		340,264 AF[74]	107,060 AF[75]
Kern County WA		1,400,000 AF[76]	176,272 AF[77]
Antelope Valley - East Kern WA[78]			18,467 AF
Kern-Tulare WD and Rag Gulch WD[79]			26,000 - 27,000 AF
Joint Powers Authority – Terra Bella ID, Lower Tule River ID, Saucelito ID, Pixley ID, and Porterville ID[80]			300,000 AF
Golden Hills CSD[81]			200 AF
Tehachapi-Cummings			
City of Santa Barbara – Goleta[82]		500 AF	
City of Oxnard[83]			3800 AF in two years
City of Santa Barbara – Foothill basin[84]	3,000 AF	1200-1500 AF	
Calleguas (In conjunction with MWDSC)[85]			10,000 AF
United WCD			
Chino Basin Watermaster[86]	Several hundred thousand AF	25,000 - 30,000 AF + 50 - 60,000 in-lieu	20,000 AF
Chino Basin WCD[87]			17,000 AF
MWDSC and			4,800 AF

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[71] Figure is calculated using the recharge rate (cfs) for facilities within the district, therefore it is the highest possible number using existing facilities and assuming water is available year round. Kern County Water Agency. Kern County Water Agency.

[72] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[73] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[74] Figure is calculated using the recharge rate (cfs) for facilities within the district, therefore it is the highest possible number using existing facilities and assuming water is available year round. Kern County Water Agency. Kern County Water Agency.

[75] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[76] Calculated from potential recharge facilities assuming 100% efficiency of recharge. Kern County Long Term Storage Supply Project Report.

[77] Kern County Water Agency. 1995. Water Supply Report. Figures are for 1993.

[78] Fuller, R., Antelope Valley - East Kern WA. July 18, 1995. Personal Communication. Through the district's in-lieu incentive program, where well owners received a discounted price for surface water. From 1976-1994, 332,409 AF of in-lieu water was provided, giving an annual average of 18,467 AF. More water is expected to be recharge due to their new incremental incentive program.

[79] Bowers, B., Kern-Tulare WD. July 1995. Personal Communication. Amount of water recharged since 1993.

[80] Robb, R., Lower Tule River ID. July 1995. Personal Communication. Estimated recharge in first year of Joint Powers Authority. Previously each of the five districts had conjunctive use programs, they are in the process of combining their projects and adopting a joint management groundwater plan.

[81] Golden Hills CSD. July 1995. Natural Heritage Institute survey results.

[82] Integrated Water Technologies, Inc. June 1995. Presented at ACWA Groundwater Mini-Conference. Program uses existing facilities, and recharging during only 4 months of the year (when water is available)

[83] Integrated Water Technologies, Inc. June 1995. Presented at ACWA Groundwater Mini-Conference.

[84] Integrated Water Technologies, Inc. June 1995. Presented at ACWA Groundwater Mini-Conference.

[85] Horne, W.June, 8, 1995. General Methods & Facilities to Expand Conjunctive Use. Presented at the ACWA 1995 Ground Water Mini-Conference Conjunctive Use

[86] Stewart, T., Chino Basin Watermaster. August 1995. Personal Communication.

[87] Gumina, Sal, Chino Basin WCD. July 1995 Natural Heritage Institute survey results.

Cucamonga CCWD[88]			
Mojave WA[89]			360,000 AF
San Fernando Basin – includes Los Angeles, Glendale, and Burbank's water rights[90]	3,200,000 AF is the size of the basin, however 200,000 AF safe storage capacity	100,000 AF	152,000 AF
Orange County WD[91]		115,000 AF more than current recharge due to new facilities	300,000 - 400,000 AF
Water Replenishment District of southern California[92]			155,000 AF + 20 - 30,000 AF from injection
Los Angeles County[93]			220,000 AF local storm 68,000 AF imported 50,000 AF reclaimed
Central and West Coast Basins[94]		450,000 AF	145,000 AF
Eastern MWD - San Jacinto Basin[95]		7,641 - 9,526	
Elsinore Valley MWD[96]			13,000 AF
Three Valleys MWD[97]		75,000 AF	
San Bernadino Valley MWD[98]	500,000 AF		
City of Oxnard[99]			2,000 AF, but with improvements will recharge 6,000 AF
Calleguas and MWD in North Las Posas Basin	300,000 AF[100]	100,000 AF[101]	
Main San Gabriel Basin[102]	8,000,000 AF total storage potential		

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[88] Metropolitan Water District of Southern California. July 1995. Regional Urban Management Plan for MWDSC.

[89] Rowe, L. July 26, 1995. Personal Communication.

[90] Blevins, M., San Fernando Basin Watermaster. June 1995. Outline of presentation at ACWA Groundwater Mini-Conference. Average annual groundwater pumping (1968 through 1993) is 86,300.

[91] Orange County Water District, 1994, Groundwater Management Plan.

[92] Water Replenishment District of Southern California. 1995. Water supply report. Garcia, Mario. July 1995. Personal Communication.

[93] Survey Response, Robert D. Pedigio, Hydraulic/Water Conservation Division, LAPWD. Figure includes amount recharged in LAPWD operated facilities for other organizations.

[94] John Norman, General Manager, WRD. Letter to Dirk Reed, MWDSC. 300,000 AF of operating storage capacity is currently being operated by WRD. Includes barrier injection, spreading of imported and reclaimed water, and in-lieur deliveries.

[95] Wang, C., B. Mortazavi., W. Liang, N. Sun, and W. Yeh. April 1995. Model Development for Conjunctive Use Study of the San Jacinto Basin, California. Water Resources Bulletin **31:** (2). p. Figure based on artificial recharge model for San Jacinto Basin.

[96] Elsinore Valley MWD. February 28, 1994. Ground Water Recharge Feasibility Study. Feasibility stage, not yet implemented.

[97] Stetson, T. June 1995. Case Studies on Implementing Conjunctive Use. Presented at ACWA Groundwater Mini-Conference on Conjunctive Use.

[98] Tincher, Bob, San Bernadino Valley MWD. August 3, 1995. Personal Communication.

[99] Arora, S., and S.Darabzand. 1990. Conjunctive Use of Surface and Groundwater Resources in the Central Valley of California, in Hydraulics/Hydrology of Arid Lands, Proceedings of the International Symposium, (ed. by R. H. French), ASCE, New York. p. 373-378.

[100] Atwater, R., The Use of Wholesale Water Rates to Encourage the Groundwater Conjunctive Use. 1990. in Hydraulics/Hydrology of Arid Lands, Proceedings of the International Symposium, (ed. by R. H. French), ASCE, New York. pp. 46-48.

[101] Horne, W.June, 8, 1995. General Methods & Facilities to Expand Conjunctive Use. Presented at the ACWA 1995 Ground Water Mini-Conference Conjunctive Use

[102] Stetson, T. June 9, 1995. Presentation at ACWA's 1995 Groundwater Mini-Conference.

Raymond Basin	100,000 AF[103]	23,600 - 31,300[104]	10,798.8 AF[105]
Sweetwater Authority[106]	120,000 - 240,000 AF		3,500 AF
San Diego River Groundwater Basin Task Force[107]			5,000 AF
City of San Diego and the San Pasqual Basin[108]			7,000 AF

Disclaimer: these figures cannot be added for a total volume of recharge because some districts are double counted, i.e. the districts report recharge, but recharge is done by another entity.

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[103] Man, D. June 8, 1995. Current Practices of Conjunctive Use in the State. Presented at ACWA 1995 Ground Water Mini-Conference Conjunctive Use.

[104] Palmer, R., Raymond Basin Management Board. July 1995. Personal Communication.

[105] Raymond Basin. 1995. Management Board Report, p. 18.

[106] Daniel Diehr, San Diego County Water Authority. July 25, 1995. Facsimile communication. Preliminary results of agency's investigation. Planned project expected to begin by 1997-98.

[107] Daniel Diehr, San Diego County Water Authority. July 25, 1995. Facsimile communication. Figure is an estimate, potential production is unknown at this time.

[108] Daniel Diehr, San Diego County Water Authority. July 25, 1995. Facsimile communication. Production figure is from an earlier study, potential production is unknown at this time.

Appendix IV: Environmental Risks

AVI.1 Risks in Changing Surface Operations

One approach to increasing system yield analyzed in this paper involves transferring water from surface storage to underground storage in advance of periods when precipitation can be anticipated. This mode of operation may lead to two kinds of negative impacts. First, since the surface reservoirs will, in general have greater empty space going into the winter, pulse flows that would normally pass through the reservoir will now be captured. This may have negative consequences downstream. Second, if reservoir levels are lowered before the winter the winter is dry, it may be more difficult to maintain instream flows and temperature control below the dam .

The environmental benefits of pulse flows is a high priority topic for additional work. Benefits may be derived from the effect of the water in transporting organisms downstream. Perhaps more important, occasional high flows are important for maintaining the natural morphology in downstream streambeds. Central Valley rivers are already highly regulated, though very high flow peaks still cannot be captured by storage. The use of groundwater storage to enhance yield would continue the historical reduction in pulse flows. The working hypothesis is that the benefits of enhanced environmental flows during critical seasons and dry years outweighs this negative effect, but more work is needed to determine whether this assumption is warranted.

As previously noted, many in-stream environmental uses depend on water temperature. Anadromous fish migration and spawning is affected by stream temperatures. Major streams such as the Sacramento and Mokelumne have temperature standards. Supplying water at these temperatures depends on maintaining thermal stratification in water supply reservoirs. Temperatures in upper levels increase during the summer but water at lower levels maintains stable temperatures and can be used to meet instream flow needs. If buffer storage levels are drawn down too far, water in the reservoirs will turn over and thermal stratification will be lost.

Risks of losing thermal stratification may increase with groundwater banking operations. Since conjunctive management necessitates partial evacuation of reservoirs in advance of precipitation, storage will inevitably be lower if the anticipated precipitation does not occur. As previously noted, California has historically faced drought periods extending for six or more years. The adequacy of groundwater banking to maintain sufficient surface storage will be most critical when this happens. Anadromous fish species have a migration cycle that spans a number of years. If spawning and other conditions are sub-optimal for individual years, overall population impacts may be minor. If sub-optimal conditions extend over consecutive years, net impacts will be substantially greater.

With groundwater banking, reservoir storage levels going into droughts will be lower than they would be under current operating procedures. Risks to in-stream flows and temperatures during this type of event depend critically on how rapidly the likelihood of a long-term deficit can be identified and how completely non-environmental users can be shifted to banked groundwater. If non-environmental demands on surface supplies can be reduced greatly before surface storage reaches critical levels, conjunctive management may increase the ability to maintain temperature stratification and surface supplies for in-stream uses. On the other hand, if operating mechanisms do not allow adequate shifts of high priority non-environmental demands from surface storage, if warning systems are insufficient to identify the probability of long-term deficits or if aggressive operating procedures result in inadequate surface reserves, temperature and in-stream flow impacts could be substantial. Current instream flow standards are often set just below dams. It is likely to be physically impossible (or at least economically impossible) to shift water from aquifer storage sites to these locations if buffer supplies prove inadequate. If buffer storage is too low, additional supplies could, potentially, be purchased from utility or district reservoirs upstream. How this might work, what it would cost and the availability of water for purchase during long-term droughts have yet to be investigated.

Beyond the environmental costs associated with conjunctive management, it is important to note that realizing many of the environmental benefits depends very heavily on operations procedures and hydraulic system configuration. The ability to shift non-environmental users onto groundwater during drought years depends on their location in relation to groundwater basins having appropriate storage characteristics. Banked water often cannot be directly applied to meet in-stream environmental needs. Aquifers are often located substantially downstream from critical environmental needs – such as spawning sites. In addition, groundwater is often warmer than water in surface streams. Since many habitat characteristics are temperature dependent, this can greatly affect the usability of banked groundwater for environmental purposes. As a result, generation of environmental benefits may depend critically on the degree to which banked water can be used to displace non-environmental demands on surface water supplies, particularly during intense drought periods. Similarly, the ability to create wetland habitat benefits depends on the match between the timing of water availability for recharge in relation to waterfowl wetland needs.[109] Overall, the environmental benefits of conjunctive management could be major – but the devil lies in specific details.

AIV.2 Recharge and Extraction Associated Risks

There is an array of potential environmental risks associated with the extraction and recharge component of any conjunctive management operation. In a broad sense these can be divided into two categories: (1) those associated with basin hydrology such as the potential for subsidence or interaction with surface stream flows; and (2) those related to water quality and pollution considerations. The first class of risks heavily depends on the degree to which the regional hydrology is accurately understood and the magnitude of flows related to storage and extraction in comparison to other flows. The second class may depend more on recharge and extraction mechanisms and agricultural chemical use patterns.

AIV.2.1 Hydrologic Uncertainty

The degree to which basin hydrologic characteristics are understood is a major factor influencing the risk of unanticipated environmental impacts. In addition, the accuracy with which the regional hydrology is understood greatly influences the degree of assurance the program has regarding ability to store and extract water in the amounts anticipated – and, thus, the overall benefits of conjunctive management.

Information on basin hydrology in the Sacramento-San Joaquin systems varies greatly depending on location. In general, the hydrology of the adjudicated basins in southern California has been quantified to a much greater degree than basins further north. This reflects the much longer history of water shortage and attempts to address it in the south compared to the north.

Characterization of the aquifer system underlying the Sacramento-San Joaquin has changed significantly over time. Early reports viewed the Sacramento basin essentially as a single unconfined aquifer and the San Joaquin essentially a two or multi-layered system in which confined and unconfined aquifers were separated by the dense and regionally extensive Corcoran Clay, or e-clay, member of the Tulare formation (Bertoldi, Johnston et al. 1991). More recently, the intensive Regional Aquifer System Analysis (RASA) study undertaken by the USGS has changed that image fundamentally. This detailed modeling effort characterized both the Sacramento and San Joaquin systems as essentially a single aquifer with multiple, discontinuous layers of low permeability clays creating semi-confined conditions in many locations (Bertoldi, Johnston et al. 1991). Study authors viewed flow within the system as linked throughout with substantial changes due to development. In some areas, vertical permeability of confining layers such as the Corcoran Clay has been reduced by 1.5 to 6 times (Bertoldi, Johnston et al. 1991, p. A26). Overall vertical flow has, however, increased by roughly an order of magnitude from conditions prior to development up to the 1970s. This was caused by leakage through wells with long perforated

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[109]. It would, for example, be important to evacuate reservoirs in the fall in advance of major precipitation periods in order to increase capture. Much of the recharge might, for this reason, need to be done in the late fall and early winter. Wetland habitat needs may, however, be particularly important in the spring and early summer.

sections (Bertoldi, Johnston et al. 1991). Most recently, work by the California DWR suggests that much of the Sacramento Valley might best be conceived as a two layer aquifer system in which extraction from or recharge to lower layers is essentially isolated from river flows.[110]

The above uncertainties have potentially great implications for conjunctive use activities. First, in parts of the Central Valley, the hydrologic system is not well enough understood at present to predict potential recharge and extraction effects on stream flows, wetlands and other associated environmental resources. This is particularly true in the Sacramento basin. Second, the same uncertainty limits the assurance a program could have regarding how much of the water it recharges will actually be available for extraction when needed and what liabilities the program might incur due to impacts on third parties. Vertical flow rates might be particularly important to this. In the Sacramento valley, for example, much would depend on whether or not recharge to deeper aquifer levels could be tapped during drought years without affecting levels in the upper unconfined aquifer or surface streams.

The above uncertainties are unlikely to represent as much of a concern in parts of the Central Valley (such as much of the San Joaquin and other groundwater basins in Southern California) where hydrological conditions are better known and where aquifers have been historically drawn down substantially or major pumping depressions currently exist. In these areas, surface-groundwater interactions are often minimal because streams are not in direct hydraulic connection with aquifers. Subsidence, while a concern, has often already occurred and, if fluctuations are kept within historical ranges, is unlikely to increase. Furthermore, because of overdraft, subsidence and other concerns, these areas have often been subject to extensive study. There is, therefore, a much larger body of information on aquifer characteristics and probable responses to the types of operations involved in a conjunctive management program. This substantially increases the degree of assurance a program would face with regard to environmental and third party impacts and the probability of stored water being available when needed.

AIV.2.2 Water Quality

A groundwater banking project of the type envisioned here should not encounter major water quality related problems in the short run. Longer term impacts are, however, much more difficult to predict. During the initial phases of a state-level conjunctive use program, water quality related problems are likely to be limited primarily to monitoring residues from agricultural operations (fertilizers and pesticides) and potential micro-element concerns in source water.[111] If direct percolation of water conveyed without intervening uses in dedicated recharge facilities is the primary recharge mechanism, source water quality should be high and problems relatively straightforward to monitor and control. Contamination is a point of concern primarily with spreading. It is also a concern if extraction causes major changes in hydraulic gradients and results in the mobilization of polluted or otherwise low quality water. This could emerge as a particular concern during long duration droughts when irrigators would be depending on groundwater as their primary source of supply over extended periods. There are two points it is important to make in this context:

1) Substantial contaminant loads including pesticides, fertilizers, salts and micro-elements such as selenium are currently isolated in the soil column. Increased flushing of the soil column due to intentional recharge (spreading) could mobilize large amounts of these contaminants. This would add to the contaminants picked up from current agricultural operations. Flushing from increased recharge could, on the other hand, have the opposite effect. Some suggest that the increased flow through aquifers resulting from conjunctive use operations could be used as a technique to reduce existing nitrate and other contamination.[112]

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[110]. Discussion with Glen Pearson, DWR on 8/17/95. In rice growing areas of the Sacramento Valley, shallow wells are observed to maintain steady water levels (lots of recharge) but deeper wells fluctuate substantially as pumping levels change. This suggests at least partial isolation of lower aquifers from upper levels.

[111]. Many conjunctive use projects envision recharge of reclaimed water. In this situation, treatment prior to injection is a major source of cost.

[112]. Personal communication, Walter Swain, U.S. Geological Survey

2) Changes in hydraulic gradients associated with extraction of stored groundwater is a major potential cause of contamination. In many locations, fresh water aquifers are in hydrologic contact with low quality water. Pumping fresh aquifers can cause intrusion of the low quality water essentially ruining them as a source or storage location. This is a common problem in coastal areas but is also of potentially great concern in many inland locations as well. On the western side of the Sacramento valley there are large areas of shallow saline groundwater that could be mobilized if hydraulic gradients change due to pumping associated with a conjunctive use program. Similar issues are present where high levels of Boron exist in groundwater making it unusable for many agricultural operations.[113]

Groundwater banking will inherently increase fluctuations in aquifer levels. This will increase both lateral and vertical flow within the groundwater system. This will, in turn, have a tendency to mobilize pollutants and naturally occurring contaminants. The net effects are, on a broad scale, difficult to predict. In some areas, increased flushing could cause net water quality improvements. In others, mobilization could have the opposite impact.

The degree to which water quality concerns are likely to emerge if conjunctive use operations are implemented is unknown. Clearly, care would be needed to avoid regions where quality problems already exist that could be exacerbated by program operations. Program exposure to potential quality problems is likely, however, to be greatest with spreading methods. These techniques are otherwise often the least costly. This suggests that direct recharge using percolation or injection techniques may, over the long term, prove less expensive because it is possible to avoid non-point sources of contamination to a much greater extent. Overall, monitoring of groundwater quality trends is particularly essential in any conjunctive management program using spreading for recharge or one that causes significant water table fluctuations to ensure that contamination from agricultural residues or other sources does not occur.

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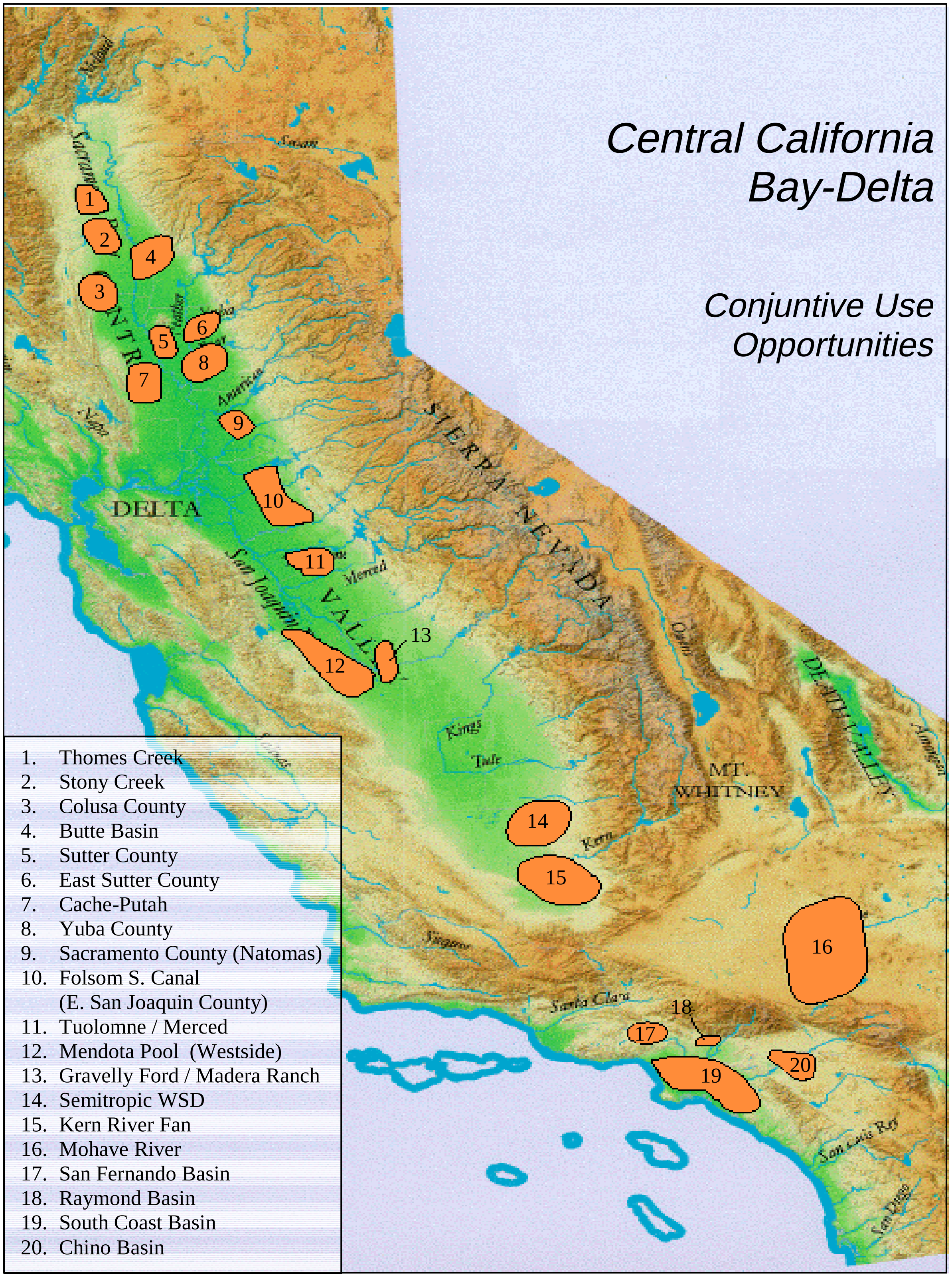
[113]. Personal Communication, Tocay Dudley, DWR, 8/21/95

Appendix V: Groundwater Banking Cost in California

Site	Cost per Acre-Foot (1994-95)	Method
Eastern Yolo County [1]	54	In lieu of irrigation
Natomas Central Mutual Water Company [2]	150	In lieu of irrigation
Pleasant Grove-Verona Mutual Water Company [2]	71	In lieu of irrigation
South Sutter Water District [2]	83	In lieu of irrigation
WID [3]	110-208	In-lieu and off season irrigation, price range depends on scale, small scale=low price. Most of difference related to additional wells and reconfiguring existing surface storage for recharge.
Antelope Valley-East Kern WA [4]	90	In lieu deliveries
Water Replenishment District of Southern California [5]	112	In lieu deliveries
Yuba County Water Agency [6]	30-35	In lieu deliveries
Leach Canyon in Riverside County [7]	141	Spreading Basins
McVicker Canyon in Riverside County [7]	176	Spreading Basins
Kern-Tulare WD and Rag Gulch WD [8]	30	Spreading Basins outside of district
Rosedale-Rio Bravo WSD [9]	10-12	Spreading Basins using excess river flow
Water Replenishment District of Southern California[10]	20	Spreading Basins using imported water. Cost/AF of imported water, depending on source can be $263, $480, or $501 11
Water Replenishment District of Southern California[10]	20	Spreading Basins using recycled water. Cost/AF of recycled water can be $15 or $380 11
Rosedale-Rio Bravo WSD [9]	50-62	Spreading Basins using SWP water
San Bernadino Valley MWD [12]	60-120	Spreading Basins
Mojave WA [13]	200	Spreading basins using SWP water
Kern County WA [14]	5-35	Spreading Basins, depending on source of water, cost for recharge alone.
Joint Management Board - Terra Bella ID, Lower Tule River ID, Saucelito ID, Pixley ID, and Porterville ID[15]	25	Spreading Basins
Average for various sites in Central Valley 16	90-120	Active percolation
Orange County WD [17]	20	Active percolation
WID & SJCID [3]	110-337	Active percolation combined with in-lieu and off-season irrigation. Price range depends on scale. Most of difference related to conveyance facilities for withdrawal.
Alameda Co. WD [18]	189	Active percolation in recharge pits and along creek bed
Raymond Basin Management Board[19]	10	Active percolation of natural run-off

Chino Basin Watermaster[20]	249	Active percolation with MWDSC SSP water
Chino Basin WCD[21]	102	Active percolation recharge
Dudley Ridge WD[22]	65-110	Active percolation recharge outside of district
Wetlands east of Lake Elsinore in Riverside County[7]	186	Injection
MWDSC with Calleguas WD in Las Posas Basin[23]	130	Injection and extraction
Raymond Basin Management Board[19]	50	Injection using discounted water from MWDSC
Arcade WD[24]	80	Combination of injection and in-lieu deliveries

1 DWR, 1994, SWP Conjunctive Use--Eastern Yolo County
2 DWR, 1995, American Basin Conjunctive Use Project, Pre-Feasibility Report, P. 125
3 EDAW, Inc. December, 1992. Draft EIS/EIR for the Updated Water Supply ManagementProgram, Volume V, Technical Appendices D1-D3 and E1-E3. Prepared for East Bay Municipal Utility District, Oakland, California.
4 Fuller, R., Antelope Valley-East Kern WA. July 18, 1995. Personal Communication.
5 Water Replenishment District of Southern California. 1995. Annual Survey and Report on Groundwater Replenishment, p. 30. In-lieu reimbursement is $112, the District uses the same rate to determine expenditures for in-lieu replenishment.
6 Wilson, D., Yuba County WA. June 1995. Personal Communication.
7 Elsinore Valley Municipal Water District, 1994, Ground Water Recharge Feasibility Study Final Report, prepared by GEOSCIENCE Support Services Inc., p. 46
8 Bowers, B., Kern-Tulare and Rag Gulch WD. July 1995. Personal Communication. $30/AF is an average estimate
9 Crossley, H., Rosedale-Riobravo WSD. June 1995. Personal Communication. Cost includes variable costs only.
10 Garcia, M., Water Replenishment District of Southern California. August 18, 1995. Personal Communication. Cost of recharge is roughly estimated to be $20/AF. Currently, the Los Angeles Department of Public Works operates and funds recharge activities, and has not calculated the cost per AF for recharge.
11 Water Replenishment District of Southern California. 1995. Annual Survey and Report on Groundwater Replenishment., p. 5.
12 Tincher, Bob, San Bernadino Valley MWD. August 3, 1995. Personal Communication. Cost figures include amount paid for recharge facilities, does not include pumping costs. Price is subsidized
13 Mojave Water Agency. May 1993. Regional Water Management Plan. Prepared by Boyle Engineering Corporation
14 Kern County WA. April 1995. 1995 KFE Property Recharge Program.
15 Robb, R., Lower Tule River ID. July 1995. Personal Communication.
16 U.S. Bureau of Reclamation and Fish and Wildlife Service, July 1995, DRAFT Conjunctive Use Technical appendix #4 to the Least-Cost CVP Yield Increase Plan, p. 6-1
17 Van Haun, J., Orange County WD. June 1995. Personal Communication.
18 Alameda County WD. February 1995. Survey Report on Groundwater Conditions. p. 21.
19 Ron Palmer, Raymond Basin Management Board. July 1995. Personal Communication.
20 Stewart, T., Chino Basin Watermaster. August 1995. Personal Communication.
21 Gumina, S., Chino Basin WCD. July 1995. Survey results.
22 Melville, D., Dudley Ridge WD., July 1995. Survey results. Cost does not include cost of water which can be highly variable.
23 Horne, W.. June, 8, 1995. General Methods & Facilities to Expand Conjunctive Use. Presents at the ACWA 1995 Ground Water Mini-Conference Conjunctive Use
24 CH2M Hill,. November 1993. Groundwater Recharge Project Feasibility Report. Prepared for Arcade Water District. Cost/AF calculated using present worth of project (20-year project life, 4% annual inflation, and 8.25% discount rate) of $28.65 million / 17,960 AF/yr * 20 years (359,200 AF) = $80/AF



Central California Bay-Delta

Conjuntive Use Opportunities

1. Thomes Creek
2. Stony Creek
3. Colusa County
4. Butte Basin
5. Sutter County
6. East Sutter County
7. Cache-Putah
8. Yuba County
9. Sacramento County (Natomas)
10. Folsom S. Canal
    (E. San Joaquin County)
11. Tuolomne / Merced
12. Mendota Pool (Westside)
13. Gravelly Ford / Madera Ranch
14. Semitropic WSD
15. Kern River Fan
16. Mohave River
17. San Fernando Basin
18. Raymond Basin
19. South Coast Basin
20. Chino Basin

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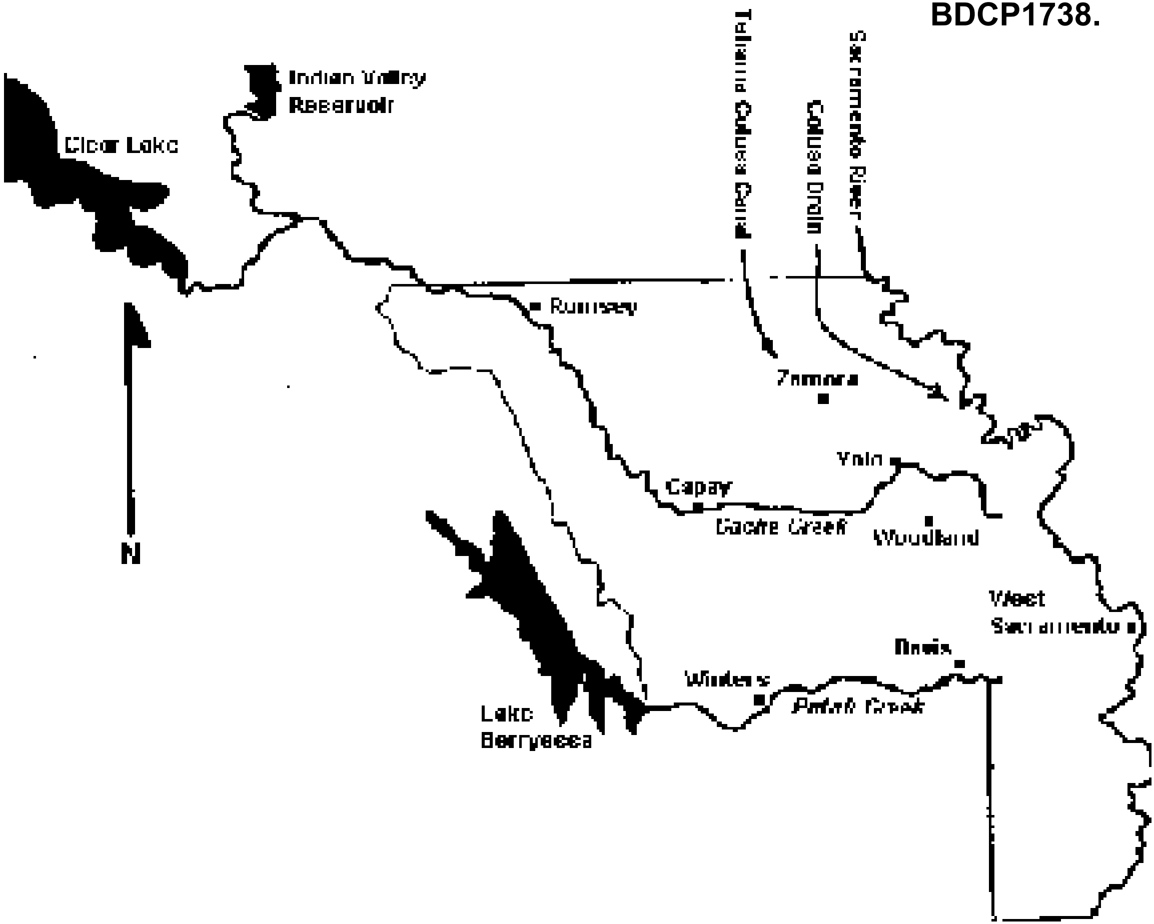
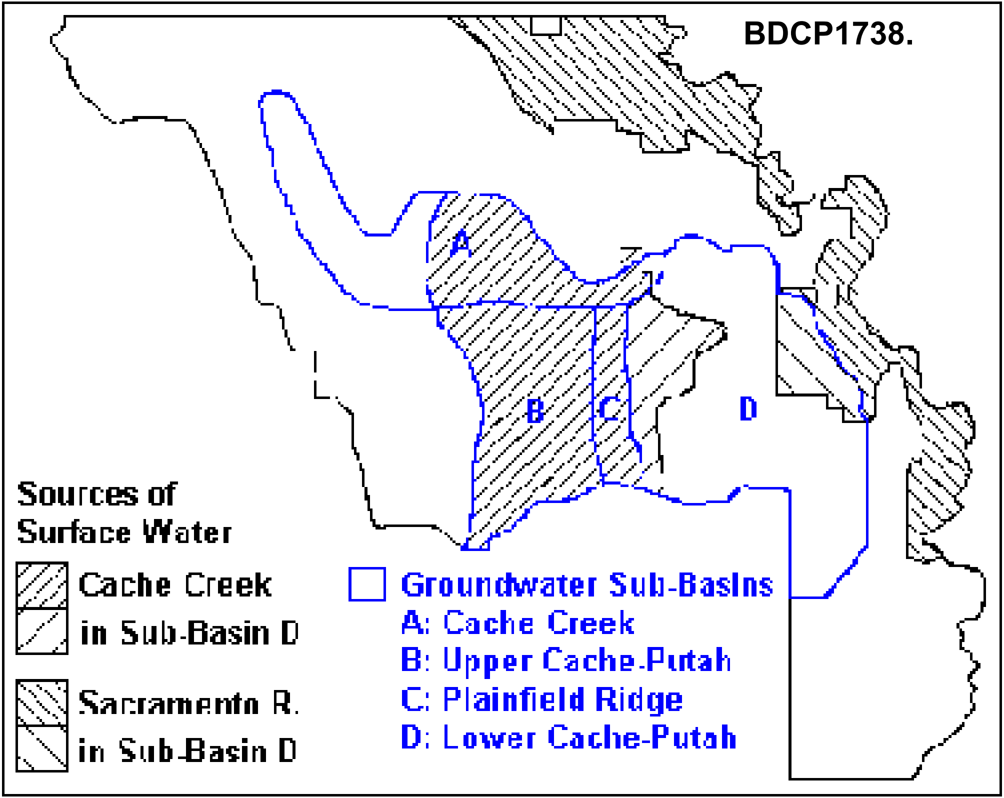

Indian Valley
Reservoir
Clear Lake
Tehama Colusa Canal
Colusa Drain
Sacramento River
Rumsey
Zamora
Yolo
Capay
Cache Creek
Woodland
West
Sacramento
Davis
Winters
Putah Creek
Lake
Berryessa
N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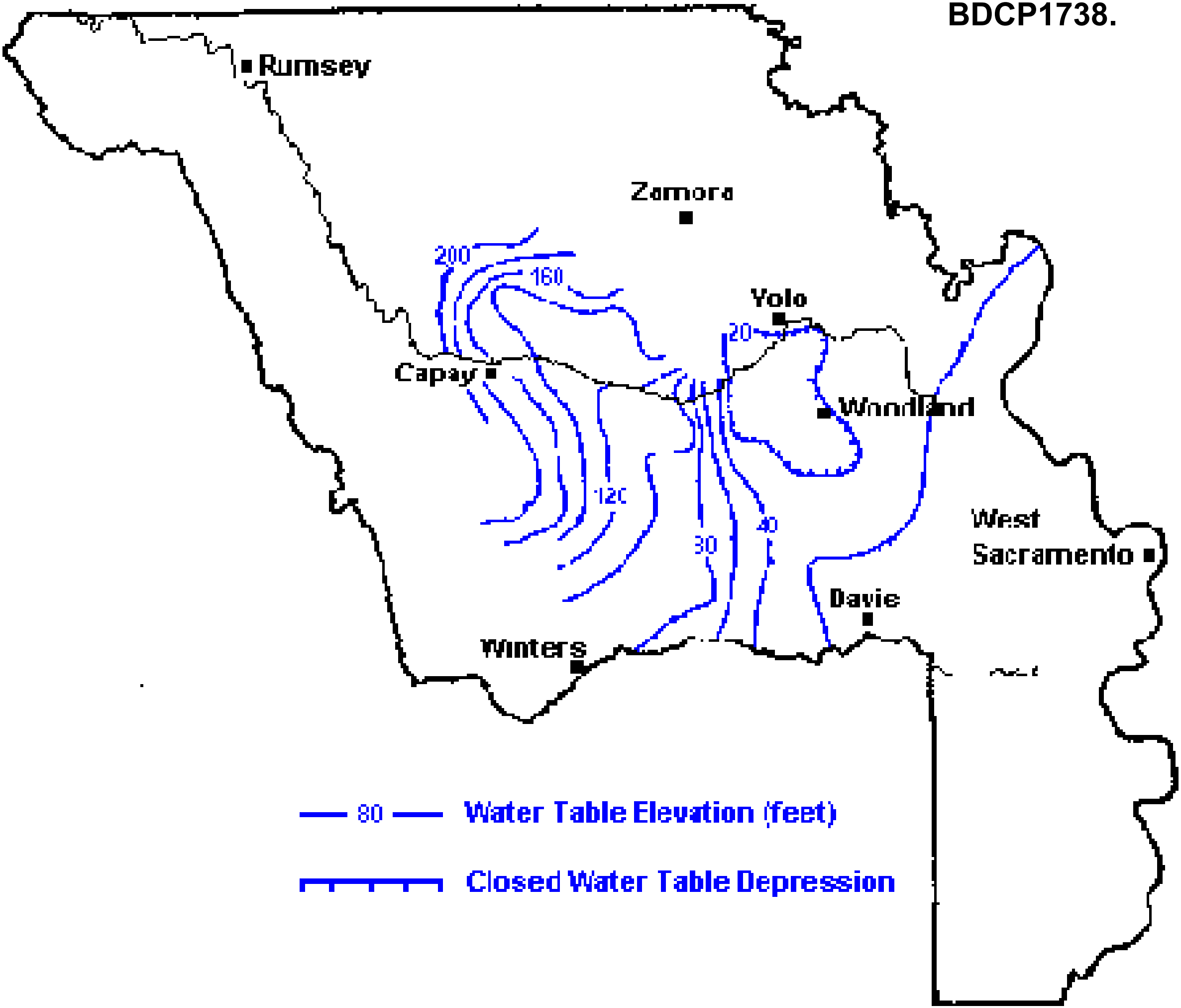
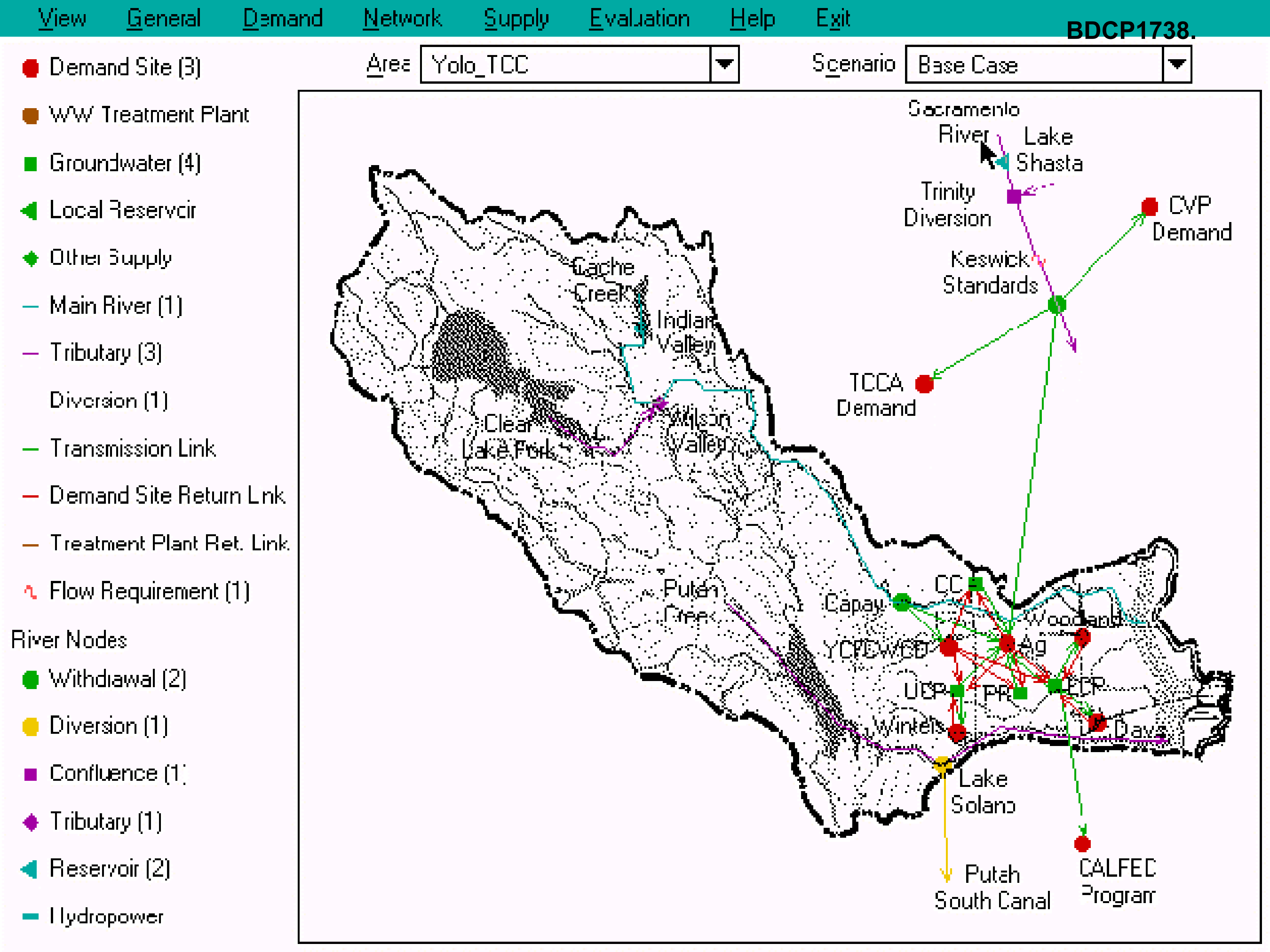
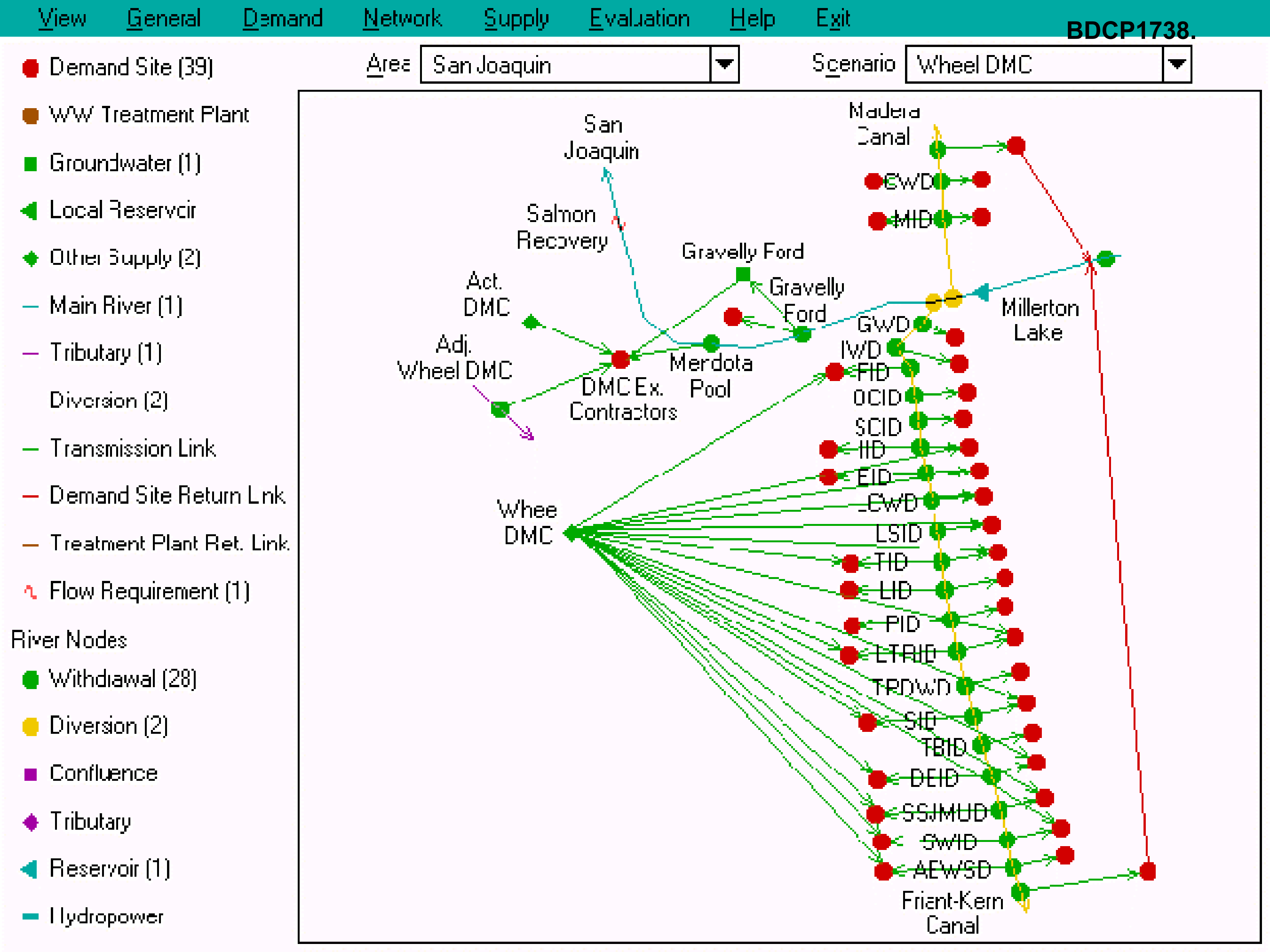
A
B
C
D
Sources of Surface Water
Cache Creek
in Sub-Basin D
Sacramento R.
in Sub-Basin D
Groundwater Sub-Basins
A: Cache Creek
B: Upper Cache-Putah
C: Plainfield Ridge
D: Lower Cache-Putah


Rumsey
Zamora
200
160
Yolo
20
Capay
Woodland
120
40
30
West
Sacramento
Davis
Winters
80
Water Table Elevation (feet)
Closed Water Table Depression



Area: Yolo_TCC

Scenario: Base Case



Area San Joaquin

Scenario Wheel DMC

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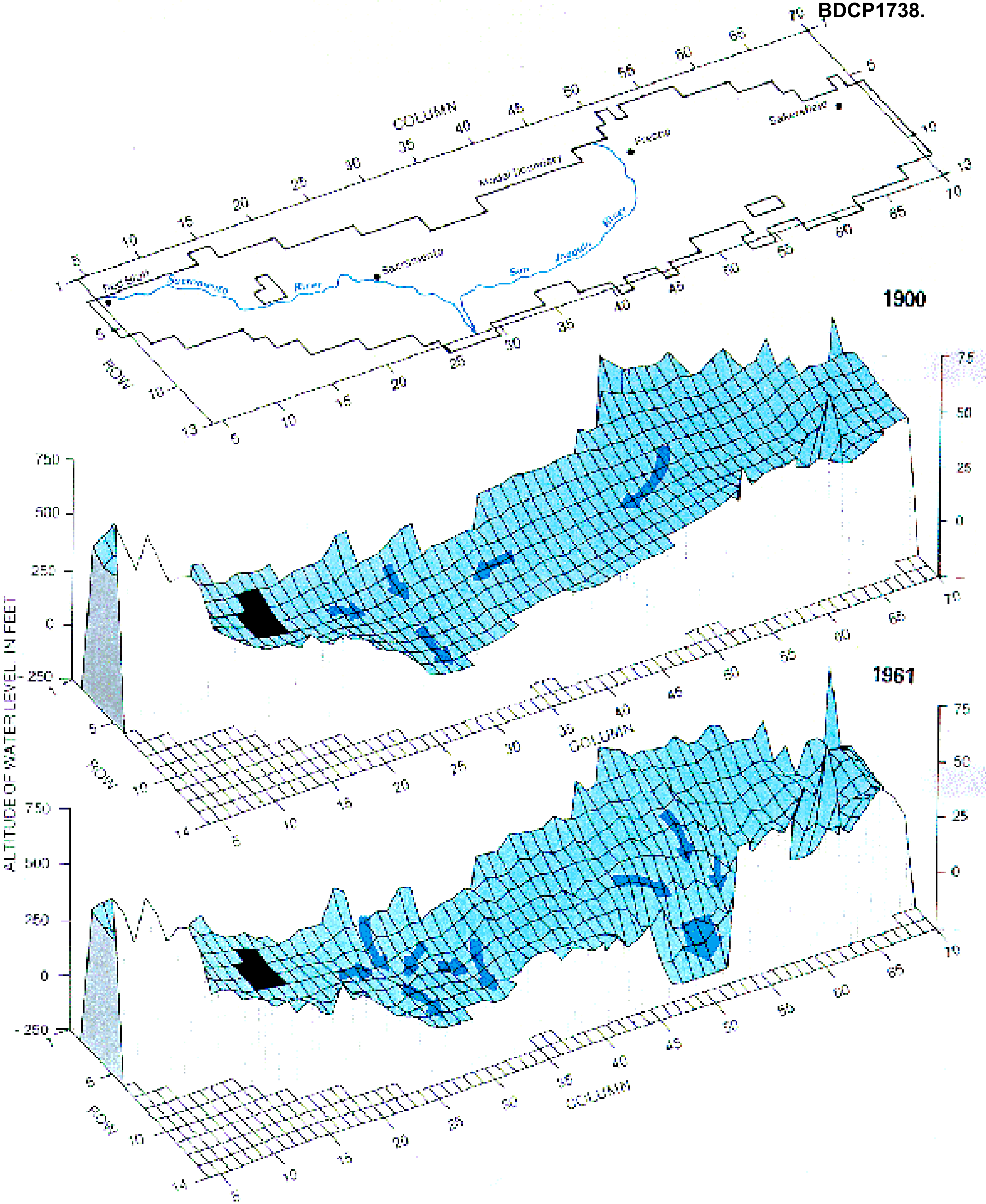
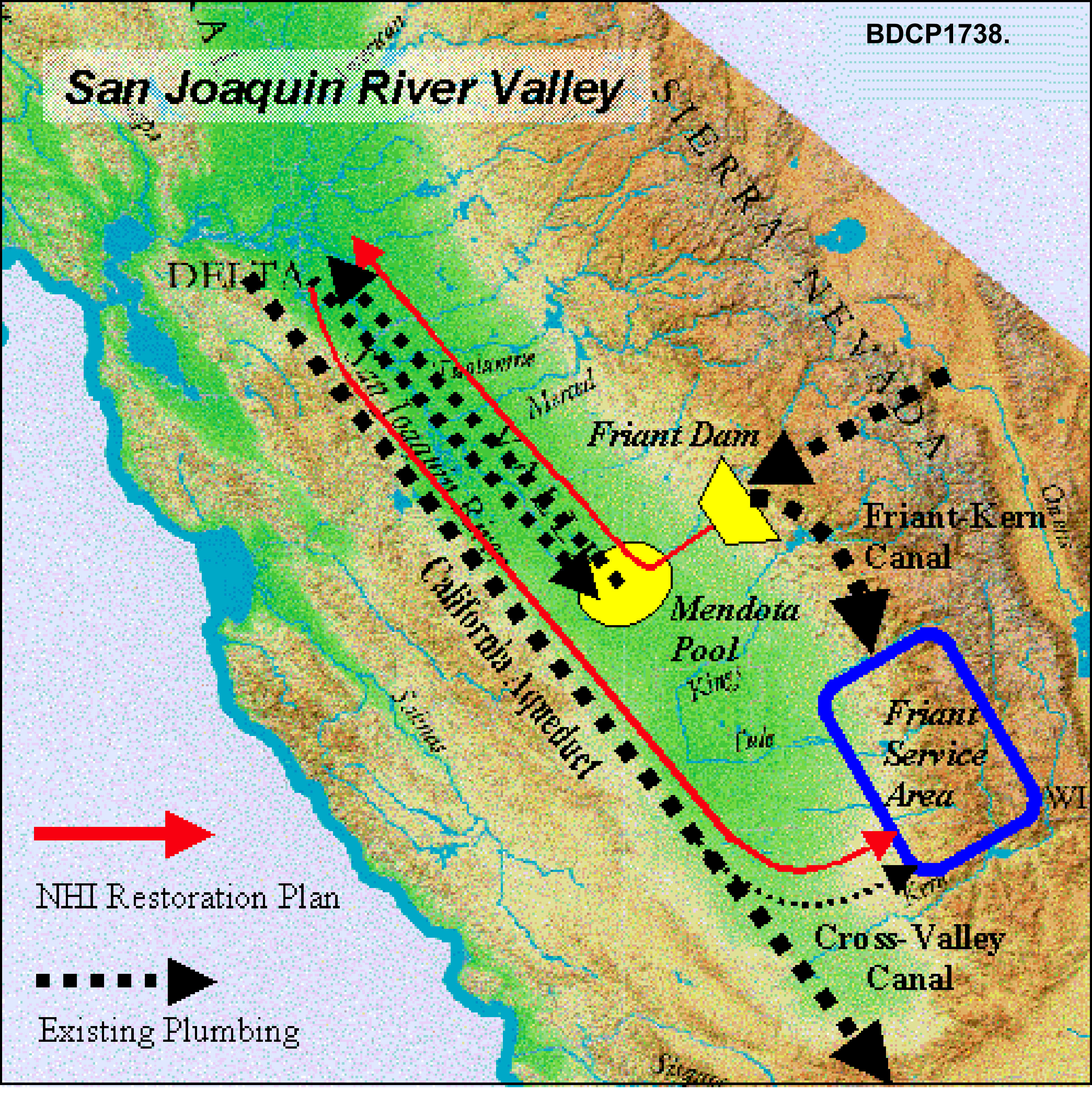
Clifton Court
Madera Ranch/ Gravelly Ford
Madera Canal
San Luis Reservoir/ O'Neill Forebay
San Joaquin River
Friant Dam/ Millerton Lake
Dos Amigos PP
Medota Pool
Delta-Mendota Canal
Friant-Kern Canal
California Aqueduct
Buena Vista PP
Cross Valley Canal


COLUMN
ROW
Red Bluff
Sacramento River
Sacramento
San Joaquin River
Fresno
Bakersfield
Model boundary
1900
1961
ALTITUDE OF WATER LEVEL, IN FEET
750
500
250
0
-250
75
50
25
0
1
5
10
13
14
15
20
25
30
35
40
45
50
55
60
65
70


San Joaquin River Valley
SIERRA NEVADA
DELTA
San Joaquin River
Tuolumne
Merced
Friant Dam
Friant-Kern Canal
Mendota Pool
Kings
Tule
Friant Service Area
Kern
Cross-Valley Canal
California Aqueduct
Salinas
Owens
NHI Restoration Plan
Existing Plumbing

RESEARCH BRIEF
Public Policy Institute *of* California
JULY 2005
ISSUE #102

Does California Have the Water to Support Population Growth?

California's population grew by over 10 million between 1980 and 2000, and it is expected to increase by another 14 million by 2030, reaching a total of 48 million. One of the most serious concerns of policymakers is whether the state will be able to supply the water needed to sustain this growth. Much of the state's population lives in areas that rely on "imported" water—water brought in from distant north-state rivers, Sierra Nevada watersheds, or even beyond California's borders. It is clear that the old way of doing business—simply damming up rivers and building aqueducts to move captured surface water—is no longer a viable strategy for accommodating this tremendous increase in population.

Policymakers and water planners have begun considering several alternative ways to bring supply and demand into balance over the years ahead. Options include expansion of nontraditional sources of supply (for example, underground storage, recycling, and desalination), reallocation through water marketing, and conservation incentives and regulations.

Although many large water projects in the past were undertaken with state and federal leadership, most current options are local or regional in scope. The California Department of Water Resources (CDWR) produces a statewide water plan every five years or so, but the frontline agencies responsible for water supply are the hundreds of municipal utilities serving the state's residential and commercial customers.

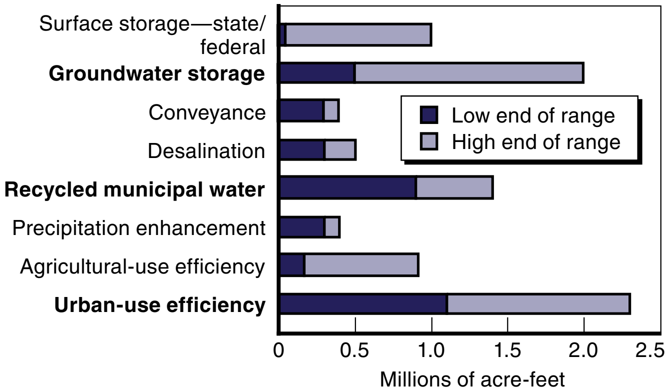
Key considerations of water demand growth are also in local hands: City and county governments are responsible for making land-use decisions—relating to general and specific plans, zoning, and subdivision maps—that affect not only the quantity but also the footprint of local development. The footprint is important because landscaping frequently accounts for more than half of all municipal water use.

In *Water for Growth: California's New Frontier*, Ellen Hanak examines how well California is faring in meeting the water supply challenges of growth. Her report examines the performance of water utilities throughout the state and draws on her original survey of local governments to see how they are integrating water supply concerns into their land-use planning.

She finds that if per capita urban water use remains at its 2000 levels of 232 gallons per person per day, California will face an expansion of water demand by 40 percent, or 3.6 million acre-feet, by 2030. Yet her review of supply options suggests that the situation may not necessarily prove dire. Ample opportunities are available over the coming decades to meet the state's needs through a diverse portfolio of conservation, groundwater banking, recycling, and water transfers that can help supplement surface storage.

Figure 1 illustrates CDWR estimates of how much water could be generated from various sources between 2000 and 2030. These estimates, which draw on assorted studies, indicate a scope for expansion well above the range of expected growth in urban and environmental demand.

Figure 1—Annual Production Potential from New Water Supply Sources and Conservation, 2000–2030



SOURCE: Department of Water Resources, "California Water Plan Update," Bulletin 160-05, Public Review Draft, Sacramento, California, April 2005.

California's water supply could be greatly increased through groundwater storage, municipal wastewater recycling, and greater efficiency in urban water use.

However, there are shortcomings with local agencies' water planning efforts. The Urban Water Management Planning Act introduced in 1983 requires that all large municipal utilities prepare a comprehensive water supply and demand planning document every five years. Yet in 2000, one-sixth of required municipal agencies submitted no water plans whatsoever, and a significant portion of submitted plans lacked detailed projections of supply and demand. Many utilities seem to be banking on "paper water" that is already being used by someone else within the state's water system. It does appear that water planning is more comprehensive and complete when water districts coordinate with other public agencies and seek information from the public on their intentions for future water use. And in terms of supply planning, there appears to be a positive movement toward recycling. But on the negative side, there seems to be limited focus on conservation and a threat of overexpansion of groundwater use in unmanaged basins.

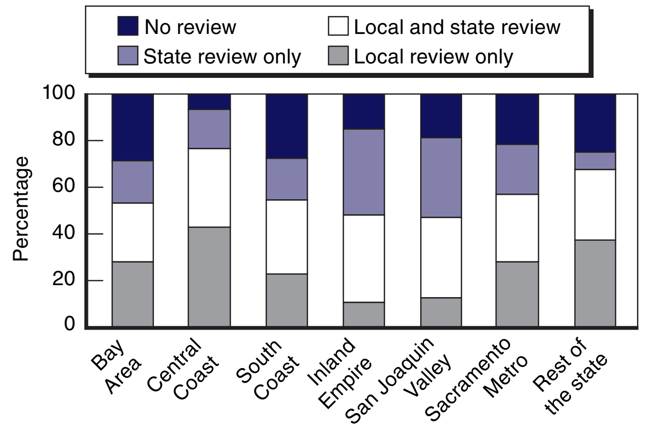
Integrating Water and Land Use

Hanak's survey of city and county land-use planners suggests that the "disconnect" between utilities and local governments is not as large as many might have imagined or feared. Six out of 10 land-use agencies participate in the planning activities of at least some of their local utilities, and nearly as many are active in water policy groups concerned with regional resource management.

A central concern has been that the local government-utility disconnect will lead to the approval of new development without adequate water supplies, putting existing and new residents at risk of shortages. However, the survey showed that over half of all cities and most counties—housing over half of the state's residents—have some form of local oversight policy to guard against this possibility (Figure 2). In addition, the passage in 2001 of Senate Bills 610 and 221—the "show me the water" bills—requires the demonstration of adequate long-term water supply before approval of large development projects. These new laws have already made their mark. Developers are being sent back to the drawing board to come up with more secure supply options, and many projects are being designed to incorporate recycling and conservation.

Appellate court rulings have also put developers, land-use authorities, and utilities on notice that project water supply assessments can be successfully challenged if they do not adequately analyze long-term supply reliability.

Figure 2—Regional Patterns of Water Adequacy Review Activity



SOURCE: PPIC land-use planner survey.

New state laws are filling a gap where local oversight policies were lacking.

Meeting the Water Supply Challenge

The author notes that although success is not guaranteed, California is well positioned to tackle the challenges of finding and managing water for growth. She points out that if communities reject growth rather than finding water supply solutions compatible with it, the state faces the prospect of more critical housing shortages. To avoid either scenario—a water shortage or a housing shortage—she argues that California's utilities and local governments must focus on four key challenges: (1) strengthening long-term water planning; (2) streamlining water adequacy screening for new development, so that local planners look carefully at the situation without unreasonably slowing housing growth; (3) realizing the potential of water conservation (especially in the fast-growing inland areas where tiered rates could do the most to moderate use); and (4) consolidating progress in groundwater management.

How Can the State Help?

To date, the state's main role has been to facilitate better local water and land-use planning through certain pieces of legislation, financial incentives, and technical support. However, water management laws have relied on citizen enforcement rather than direct state oversight. Billions of dollars in state water bond funds have enabled the state to reward local entities for taking positive actions. Yet, the author suggests, there is more room for regulatory actions—in particular, withholding new water-rights permits, as a way to encourage local entities to manage water resources responsibly.

This research brief summarizes a report by Ellen Hanak, Water for Growth: California's New Frontier *(2005, 196 pp., $15.00, ISBN 1-58213-108-2). The report may be ordered online at www.ppic.org or by phone at (800) 232-5343 or (415) 291-4400 [outside mainland U.S.]. A copy of the full text is also available at www.ppic.org. The Public Policy Institute of California is a private, nonprofit organization dedicated to independent, objective, nonpartisan research on economic, social, and political issues affecting California.*

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State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
DIVISION OF FLOOD MANAGEMENT

Fact Sheet

Sacramento River Flood Control Project Weirs and Flood Relief Structures

December 2010
Flood Operations Branch

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Overview

Sacramento Valley has a history of floods and management of floods that goes back as long as people have populated the region. Prior to flood management, the valley floor would be blanketed by seasonal runoff nearly every year; the Sacramento Valley was once nicknamed the "inland sea." This tendency to flood results from the geography of the region as well as the weather. The occasionally large amounts of rain that fall in the surrounding Coastal ranges and the relatively steep Sierra Nevada mountain ranges produce rapid surface water runoff to the Sacramento River. The amount of this surface water runoff can be quite large, depending on the amount of rainfall, snow melt, and soil moisture of the watershed. Fast water flowing from the mountains is blunted by the relatively shallow grade of the Sacramento River south of the city of Red Bluff, and would often overtop the river banks. In addition, The Sacramento River would begin depositing sediment in the more shallow grades that would often alter its direction of flow. In order to control these storm flows that would otherwise flood farmland and cities, the Sacramento River Flood Control Project (the Project) was created.

The Project was designed with the understanding that runoff from many of the storm events experienced in the Sacramento River watershed cannot be contained within the banks of the river. Nor could this flow be fully contained within a levee system without periodically flooding adjacent property. Thus, the Project was designed to occasionally spill through a system of weirs and flood relief structures into adjacent basins. These basins are designed to contain flood waters and channel them downstream, to eventually be conveyed back into the Sacramento River near Knights Landing and Rio Vista. Dry weather flows are contained within levees near the river banks and land within the flood basins is then used for agricultural purposes.

There are ten overflow structures in the Project (six weirs, three flood relief structures, and an emergency overflow roadway) that serve a similar function as pressure relief valves in a water supply system. Weirs are lowered sections of levees that allow flood flows in excess of the downstream channel capacity to escape into a bypass channel or basin.

All six weirs of the Project (Moulton, Colusa, Tisdale, Fremont, Sacramento, and Cache Creek) consist of the following: (1) a fixed-level, concrete overflow section; followed by (2) a concrete, energy-dissipating stilling basin; with (3) a rock and/or concrete erosion blanket across the channel beyond the stilling basin; and (4) a pair of training levees that define the weir-flow escape channel.

All overflow structures except the Sacramento Weir pass floodwaters by gravity once the river reaches the overflow water surface elevation. The Sacramento Weir has gates on top of the overflow section that hold back floodwaters until opened manually by the Department of Water Resources' Division of Flood Management.

Four other relief structures are concentrated along 18 river miles between Big Chico Creek (River Mile 194) and the upstream end of the left (east) bank levee of the Sacramento River Flood Control Project (near River Mile 176). These structures function like weirs but are not called weirs because they do not have all four structural characteristics previously described. All of these relief structures convey water into the Butte Basin (a natural trough east of the river) upstream of the levee system designed to guide the flood waters.

Three of the structures are designated as flood relief structures (M&T, 3B's, and Goose Lake). If these three fail as designed a raised 6,000-foot roadway near the south end of Parrott Ranch allows excess floodwaters to escape the Sacramento River to the Butte Basin before being confined by the downstream project levees.

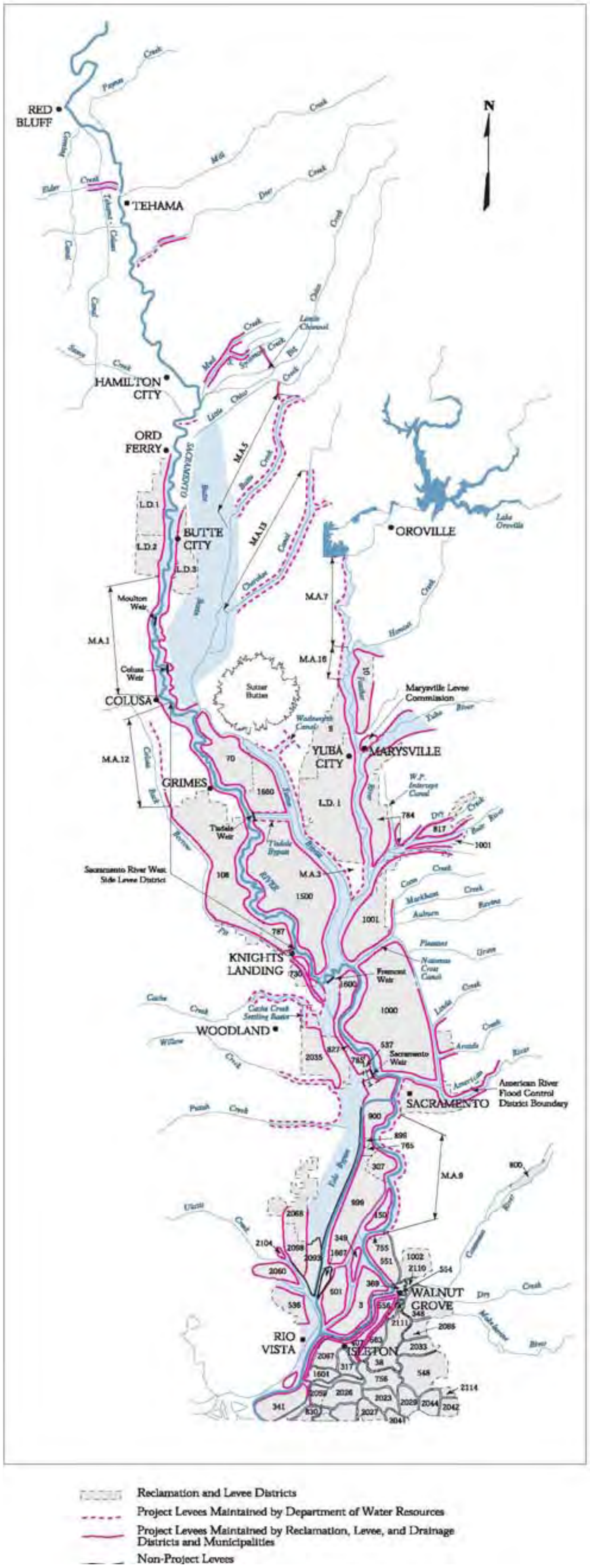


Figure 1 (above), Location Map for Weirs and Relief Structures in the Sacramento River Flood Control Project

Figure 2 (right), Sacramento River Flood Control Project Overview, showing project levees and basins

Moulton Weir

Moulton Weir was completed in 1932. It is located along the easterly side (left bank looking downstream) of the Sacramento River approximately eight miles north of the town of Colusa and about 100 miles north of Sacramento. Its primary function is to release overflow waters of the Sacramento River into the Butte Basin at such times when floods exceed the safe carrying capacity of the main channel of the Sacramento River downstream from the weir. The fixed crest reinforced concrete weir is 500 feet long with concrete abutments at each end. The outlet channel is flanked by training levees and is approximately 3,000 feet long. The crest elevation is 76.75 feet and the project design capacity of the weir is 25,000 cubic feet per second (cfs). The Moulton Weir is typically the last of the non-gated weirs to overtop, and spills for the shortest duration.

Figure 3, Moulton Weir, January 1997

Colusa Weir and Bypass

Colusa Weir was completed in 1933. It is located along the left bank of the Sacramento River one mile north of the town of Colusa. Its primary function is to release overflow waters of the Sacramento River into the Butte Basin. The fixed crest reinforced concrete weir is 1,650 feet long and is flanked by training levees that connect the river to the basin. The crest elevation is 61.80 feet and the project design capacity of the weir is 70,000 cfs. Normally, the Colusa Weir does not overtop until the Tisdale Weir is also spilling, except for flood events that are characterized by rapid rise in Sacramento River stage.

Figure 4, Colusa Weir, January 1997

Tisdale Weir and Bypass

Tisdale weir was completed in 1932. It is located along the left bank of the Sacramento River about ten miles southeast of the town of Meridian and about 56 miles north of Sacramento. Its primary purpose is to release overflow waters of the Sacramento River into the Sutter Bypass via the Tisdale Bypass. The fixed crest reinforced concrete weir is 1,150 long. The four-mile leveed bypass channel (Tisdale Bypass) connects the river to the Sutter Bypass. The crest elevation is 45.45 feet and the project design capacity of the weir is 38,000 cfs. Typically, the Tisdale Weir is the first of the five weirs in the Sacramento River Flood Control System to overtop, and continues to spill for the longest duration.

Figure 5, Tisdale Weir and Tisdale Bypass (Sutter Bypass in background, January 1997

Fremont Weir

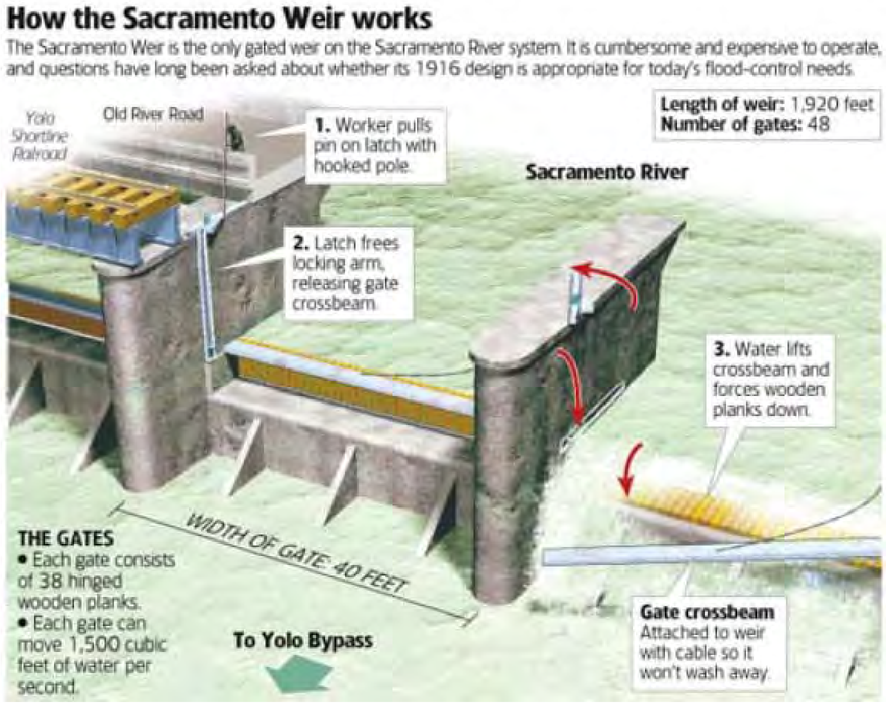
Fremont Weir was completed in 1924. It is the first overflow structure on the river's right bank and its two-mile overall length marks the beginning of the Yolo Bypass. It is located about 15 miles northwest of Sacramento and eight miles northeast of Woodland. South of this latitude the Yolo Bypass conveys 80 percent of the system’s floodwaters through Yolo and Solano Counties until it connects to the Sacramento River a few miles upstream of Rio Vista. The weir’s primary purpose is to release overflow waters of the Sacramento River, Sutter Bypass, and the Feather River into the Yolo Bypass. The crest elevation is 33.50 feet and the project design capacity of the weir is 343,000 cfs.

Figure 6, Fremont Weir (Sutter Bypass on left, and Yolo Bypass on right)

Sacramento Weir and Bypass

The Sacramento Weir was completed in 1916. It is the only weir that is manually operated – all others overflow by gravity on their own. It is located along the right bank of the Sacramento River approximately 4 miles upstream of the Tower Bridge, and about 2 miles upstream from the mouth of the American River. Its primary purpose is to protect the City of Sacramento from excessive flood stages in the Sacramento River channel downstream of the American River. The weir limits flood stages (water surface elevations) in the Sacramento River to project design levels through the Sacramento/West Sacramento area. The project design capacity of the weir is 112,000 cfs.

It is 1,920 feet long and consists of 48 gates that divert Sacramento and American River floodwaters to the west down the mile-long Sacramento Bypass to the Yolo Bypass. Each gate has 38 vertical wooden plank "needles" (4 inches thick by 1 foot wide by 6 feet long), hinged at the bottom and retained at the top by a hollow metal beam. The beam is manually released using a latch. Flood forecasters provide the necessary predictive information to weir operators who manage the number of opened gates in order to control the river's water surface elevation. Closing the hinged gates is a more laborious process than opening them. While opening a gate takes only a matter of minutes, closing it can take up to an hour. Long, hooked poles are used to raise each gate from its free open position to the vertical upright position. The hollow metal beam is then replaced, and the gate is released and allowed to rest against it.


How the Sacramento Weir works

The Sacramento Weir is the only gated weir on the Sacramento River system. It is cumbersome and expensive to operate, and questions have long been asked about whether its 1916 design is appropriate for today's flood-control needs.

Figure 7. Diagram Depicting the Opening of the Sacramento Weir.
Appeared in the Sacramento Bee on January 5, 2006.

The Department of Water Resources operates the weir according to regulations established by the U.S. Army Corps of Engineers. The opening and closing criteria have been optimized to balance two goals: (1) minimize sediment deposition due to decreased flow velocities downstream from the weir to the mouth of American River; and (2) limit the flooding of agricultural lands in the Yolo Bypass until after they have been inundated by floodwaters over Fremont Weir.

Though the weir crest elevation is 24.75 feet, the weir gates are not opened until the river reaches 27.5 feet at the I Street gage with a forecast to continue rising. This gage is about 1,000 feet upstream from the I Street Bridge and about 3,500 feet downstream from the mouth of the American River. The number of gates to be opened is determined by the NWS/DWR river forecasting team to meet either of two criteria: (1) to prevent the stage at the I Street gage from exceeding 29 feet, or (2) to hold the stage at the downstream end of the weir to 27.5 feet. Once all 48 gates are open, Sacramento River stages from Verona to Freeport may continue to rise during a major flood event. Project design stages are 41.3 feet at Verona, 31.5 feet at the south end of the Sacramento Weir, and 31 feet at the I Street gage.

Figure 8, Sacramento Weir with Yolo Bypass in foreground, January 1997

Figure 9, Sacramento Weir with American River in background, March 1995 (30,000 cfs)

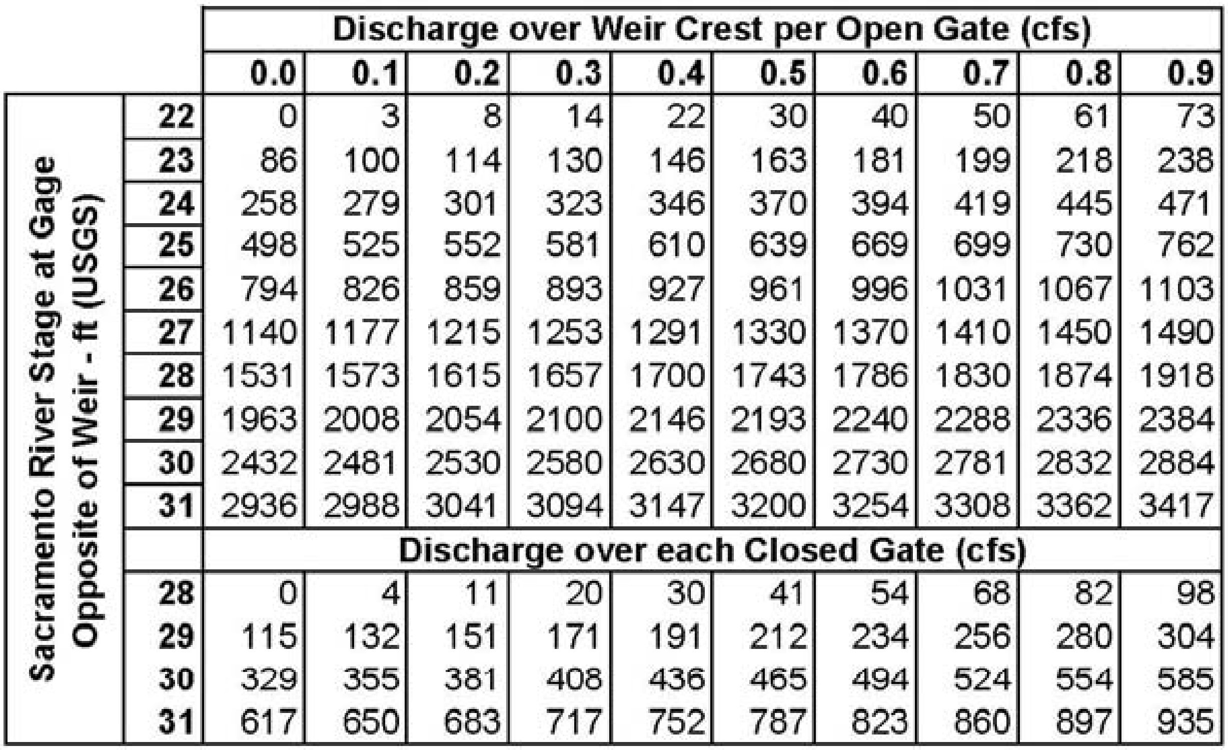
During a major flood, opening the weir gates at river stages below 27.5 feet does not reduce ultimate peak flood stages in the Sacramento River from Verona to Freeport. Diversion of the majority of upstream floodwaters to the Yolo Bypass from Fremont Weir controls Sacramento River flood stages at Verona.

Downstream of the Sacramento Weir, the design flood capacity of the American River is 5,000 cfs higher than that of the Sacramento River. Flows from the American River channel during a major flood event often exceed the capacity of the Sacramento River downstream of the confluence. When this occurs, floodwaters flow upstream from the mouth of the American River to the Sacramento Weir.

The weir gates are closed as rapidly as practicable once the stage at the weir drops below 25 feet. This provides "flushing" flows to re-suspend sediment deposited in the Sacramento River between the Sacramento Weir and the American River during the low flow periods when the weir is open during the peak of the flood event.

A rating table has been developed to estimate flow over the Sacramento Weir into the Yolo Bypass (Table 1). This table can be used to calculate both the approximate discharge per open gate and, for higher stages, the approximate discharge over closed gates as well. All stages are listed with respect to USGS mean sea level datum.

Table 1. Rating Table for the Sacramento Weir.



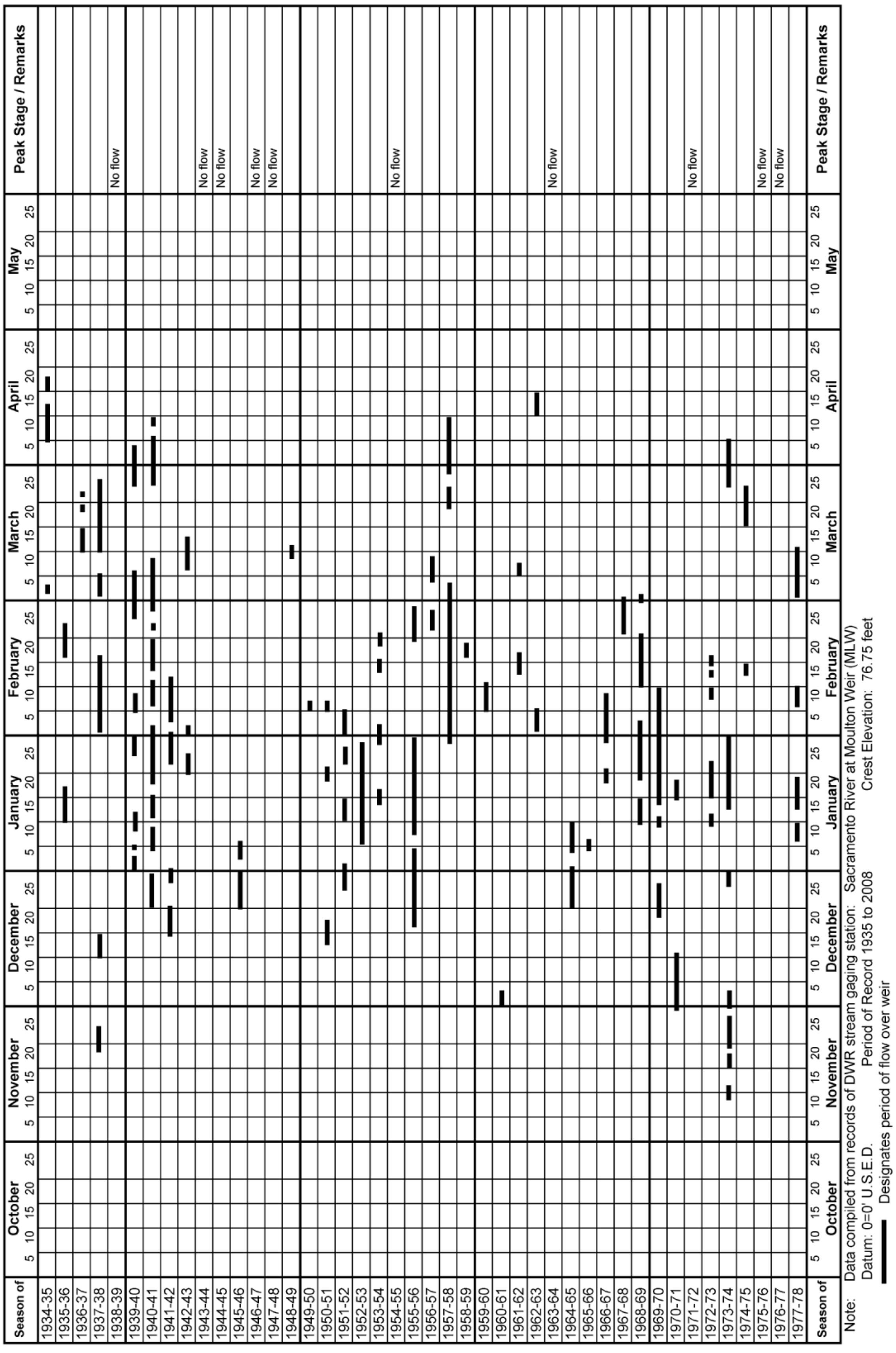
		Discharge over Weir Crest per Open Gate (cfs)									
		0.0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
Sacramento River Stage at Gage Opposite of Weir - ft (USGS)	**22**	0	3	8	14	22	30	40	50	61	73
	23	86	100	114	130	146	163	181	199	218	238
	24	258	279	301	323	346	370	394	419	445	471
	25	498	525	552	581	610	639	669	699	730	762
	26	794	826	859	893	927	961	996	1031	1067	1103
	27	1140	1177	1215	1253	1291	1330	1370	1410	1450	1490
	28	1531	1573	1615	1657	1700	1743	1786	1830	1874	1918
	29	1963	2008	2054	2100	2146	2193	2240	2288	2336	2384
	30	2432	2481	2530	2580	2630	2680	2730	2781	2832	2884
	31	2936	2988	3041	3094	3147	3200	3254	3308	3362	3417
		Discharge over each Closed Gate (cfs)									
	28	0	4	11	20	30	41	54	68	82	98
	29	115	132	151	171	191	212	234	256	280	304
	30	329	355	381	408	436	465	494	524	554	585
	31	617	650	683	717	752	787	823	860	897	935

Cache Creek Settling Basin and Weir

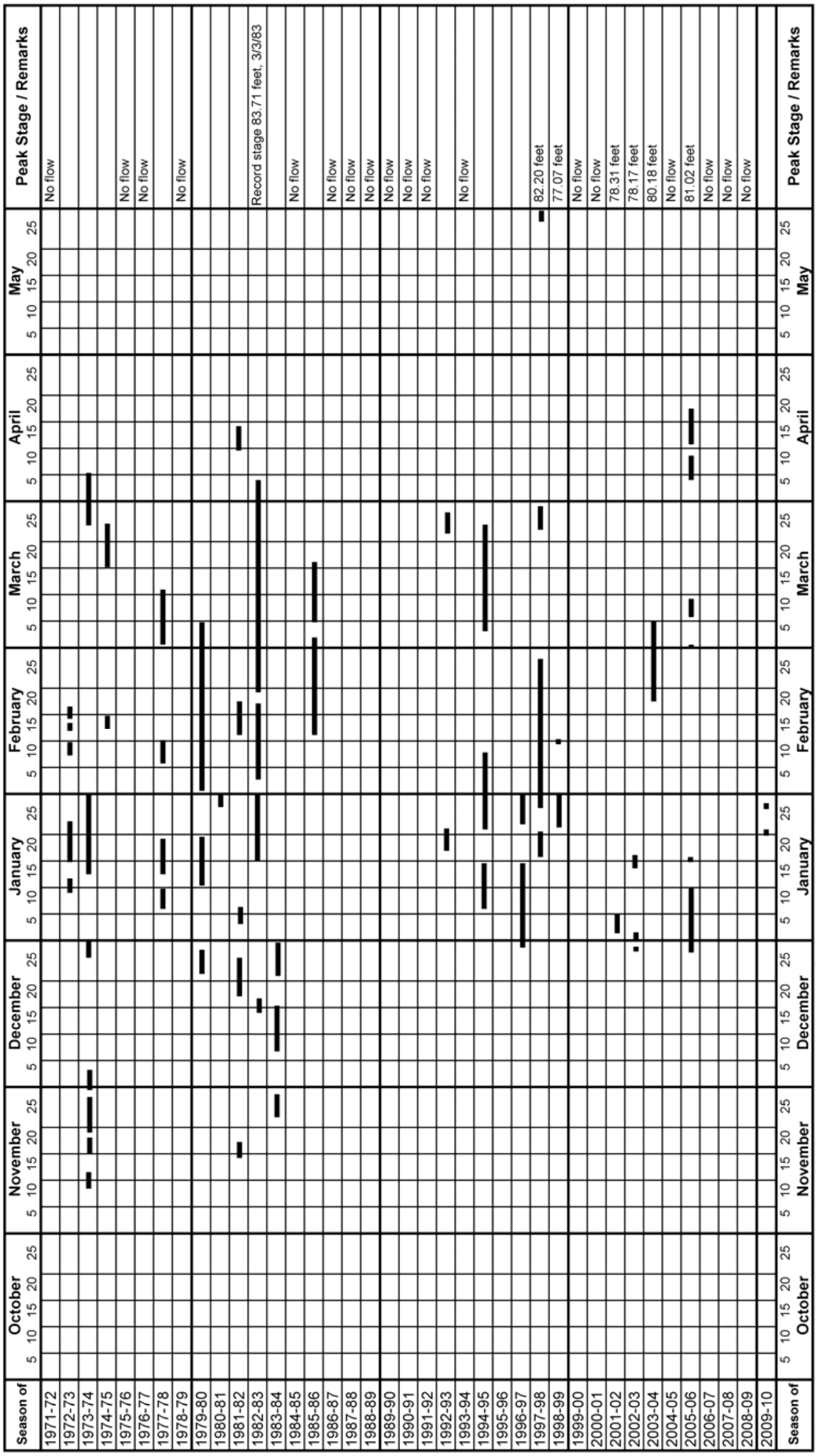
The Cache Creek Settling Basin and Weir were originally completed between the late 1930's through the early 1950's. The basin was expanded and the new weir was completed in 1991. It is located in Yolo County about two miles east of the City of Woodland. Its primary purpose is to preserve the floodway capacity of the Yolo Bypass by entrapping the heavy sediment load carried by Cache Creek before its waters pour into the bypass. The basin is bound by levees on all sides and covers approximately 3,600 acres. The roller compacted concrete weir is 1,740 feet long along the east levee of the basin and controls discharge to the bypass. The project design capacity of the weir is 30,000 cfs, which is also the maximum capacity of the upstream Cache Creek channel system.

Figure 10, Cache Creek Settling Basin Weir, March 1995

Overflow records for Moulton, Colusa, Tisdale, Fremont, and Sacramento Weirs from 1934 through 2007 are found on the following pages. Subsequent years will be added as the charts are updated.



Note: Data compiled from records of DWR stream gaging station: Sacramento River at Moulton Weir (MLW)
Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 76.75 feet
▌ Designates period of flow over weir

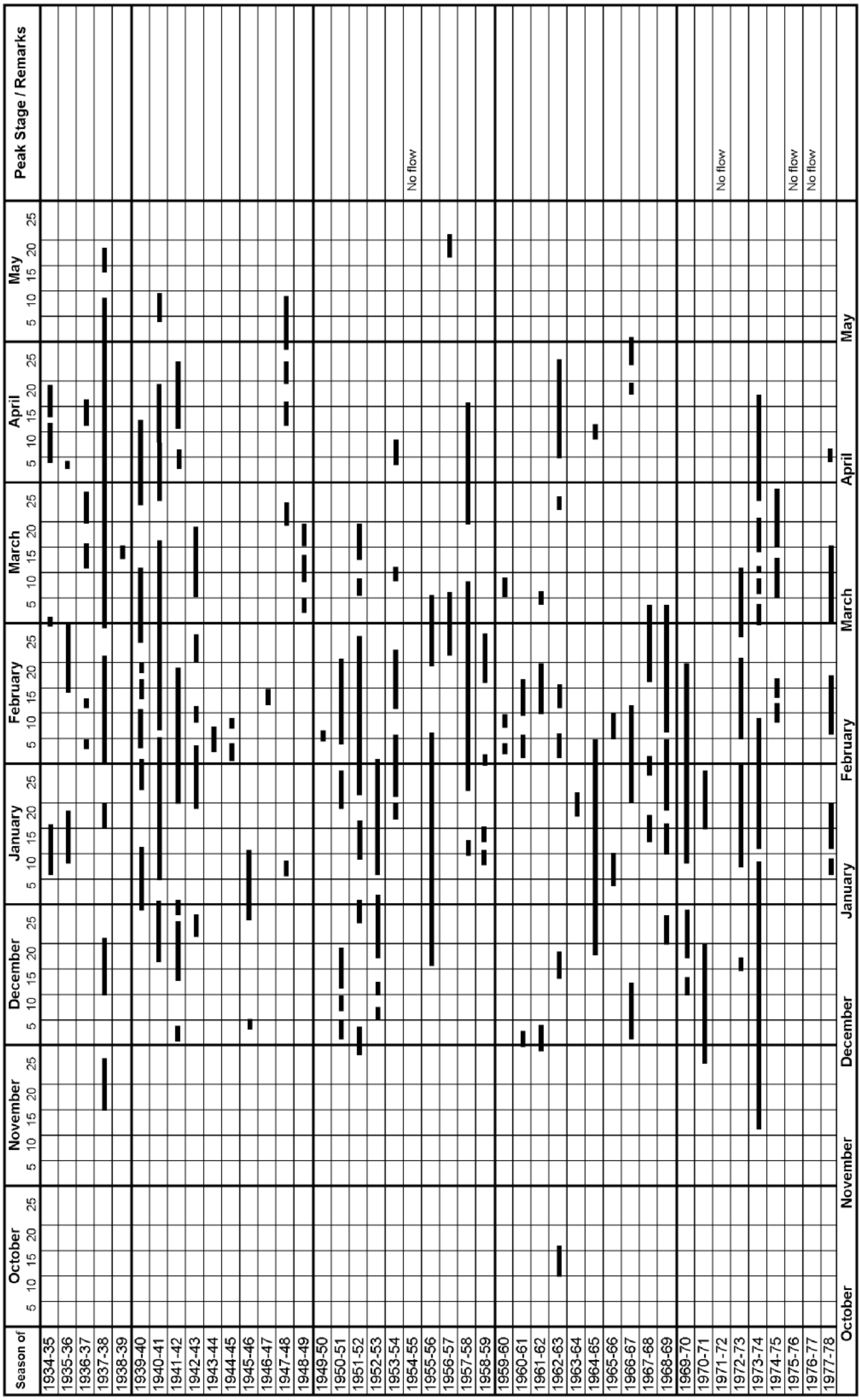


Note: Data compiled from records of DWR stream gaging station: Sacramento River at Moulton Weir (MLW)

Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 76.75 feet

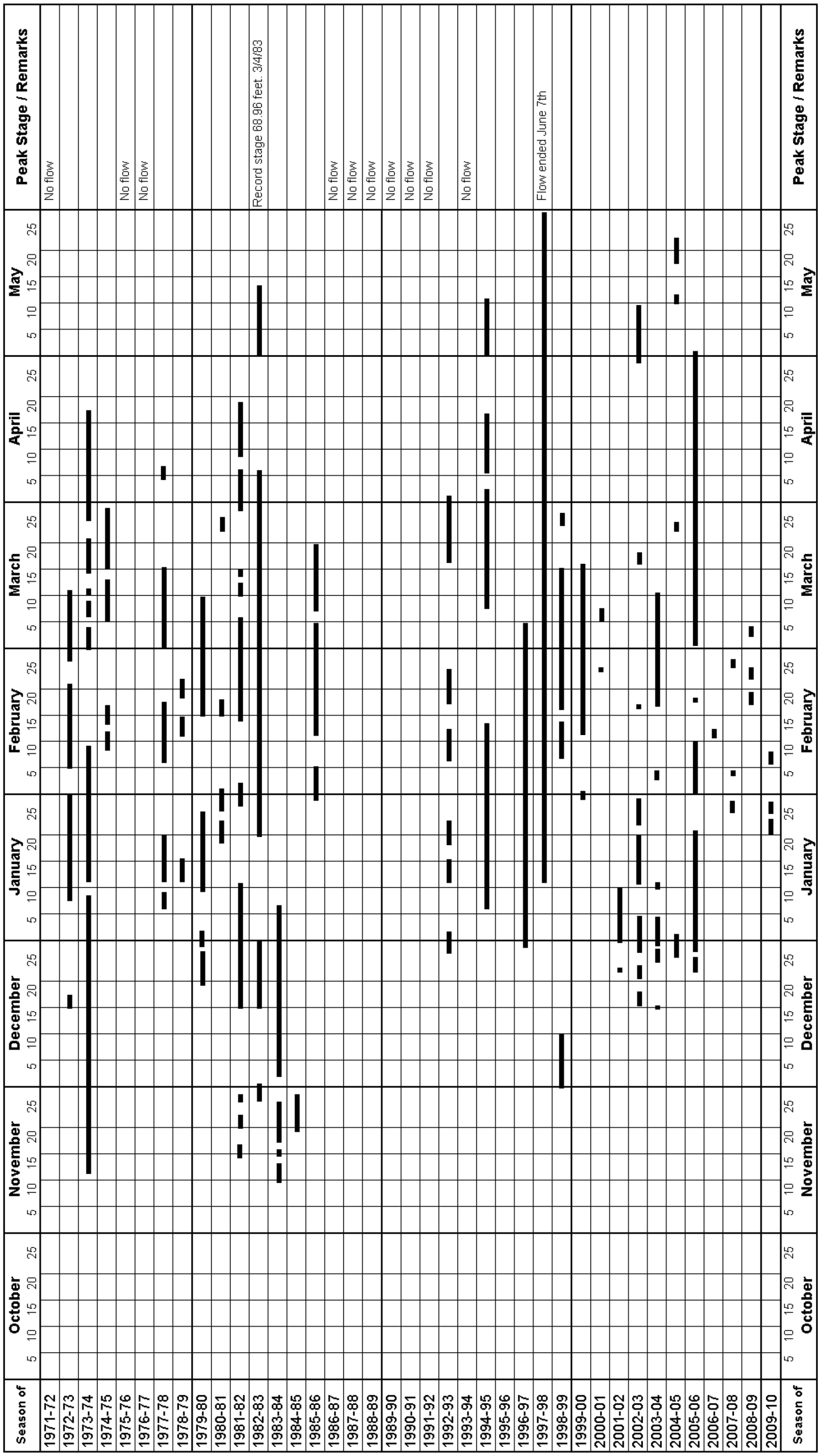
▬ Designates period of flow over weir

Colusa Weir Overflow Period of Record



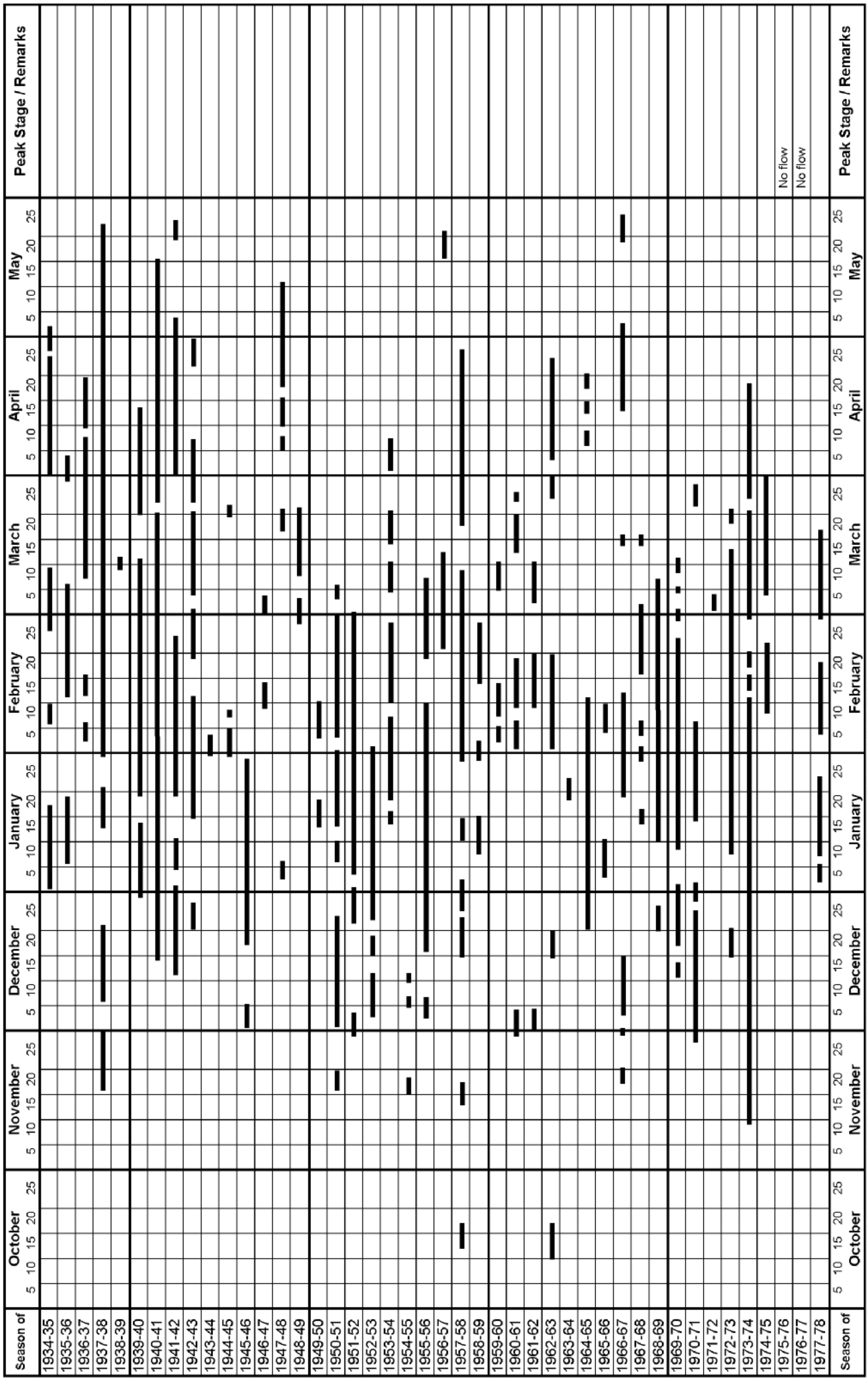
Note: Data compiled from records of DWR stream gaging station: Sacramento River at Colusa Weir (CLW)
Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 61.80 feet

▬ Designates period of flow over weir



Note: Data compiled from records of DWR stream gaging station: Sacramento River at Colusa Weir (CLW)
Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 61.80 feet
▬ Designates period of flow over weir

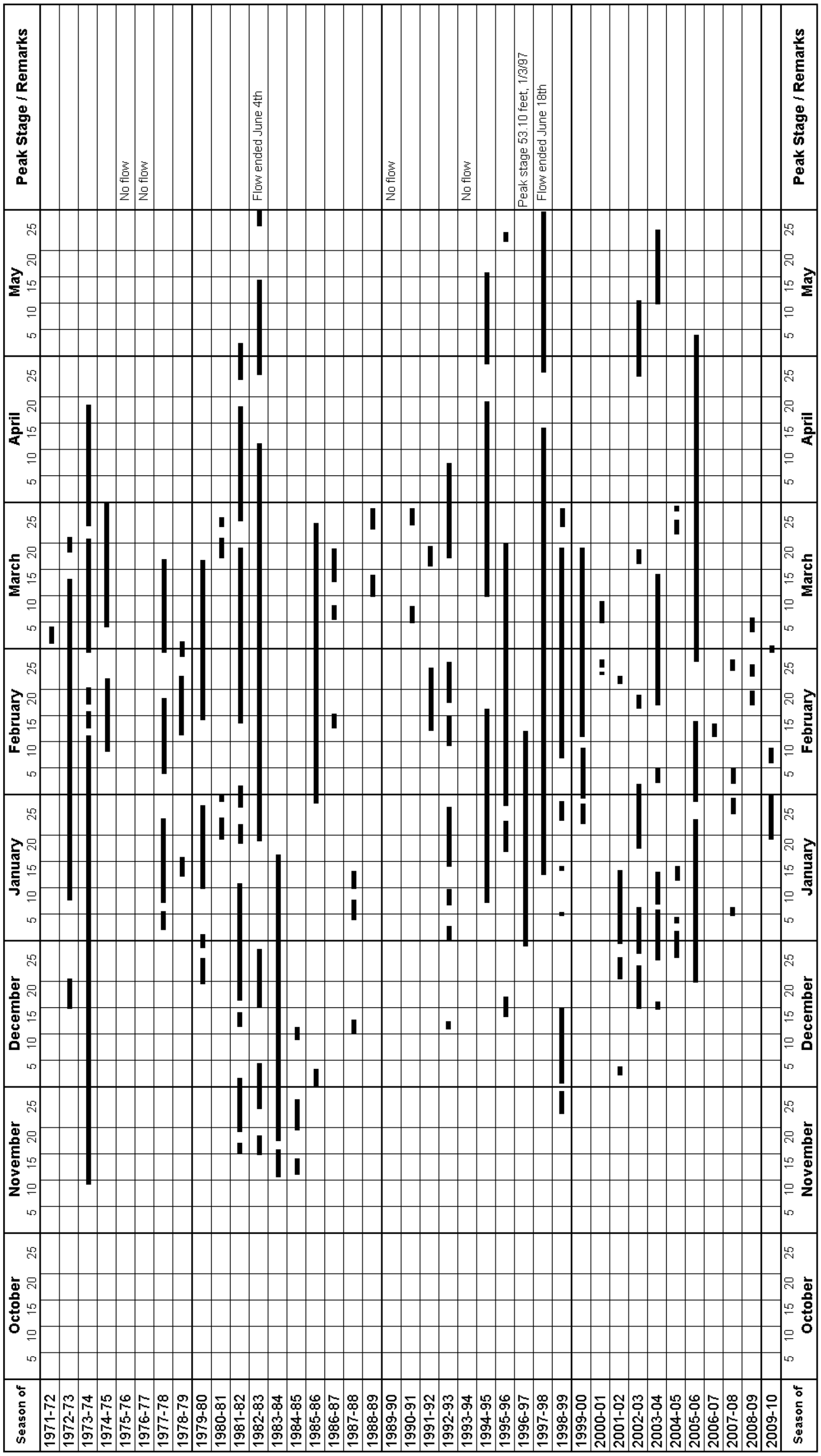
Tisdale Weir Overflow Period of Record



Note: Data compiled from records of DWR stream gaging station: Sacramento River at Tisdale Weir (TIS)

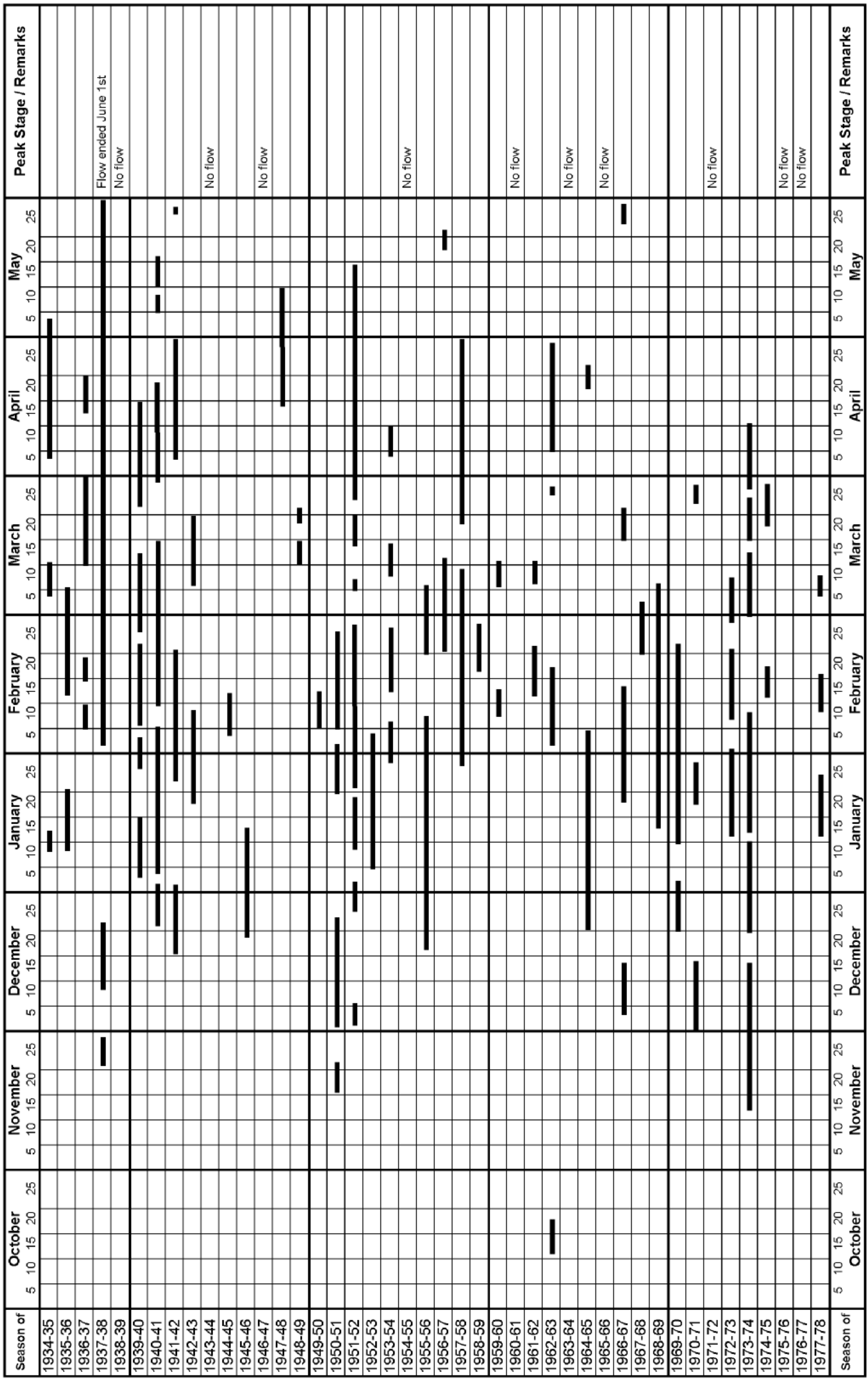
Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 45.45 feet

▬ Designates period of flow over weir



Note: Data compiled from records of DWR stream gaging station: Sacramento River at Tisdale Weir (TIS)
Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 45.45 feet
▬ Designates period of flow over weir

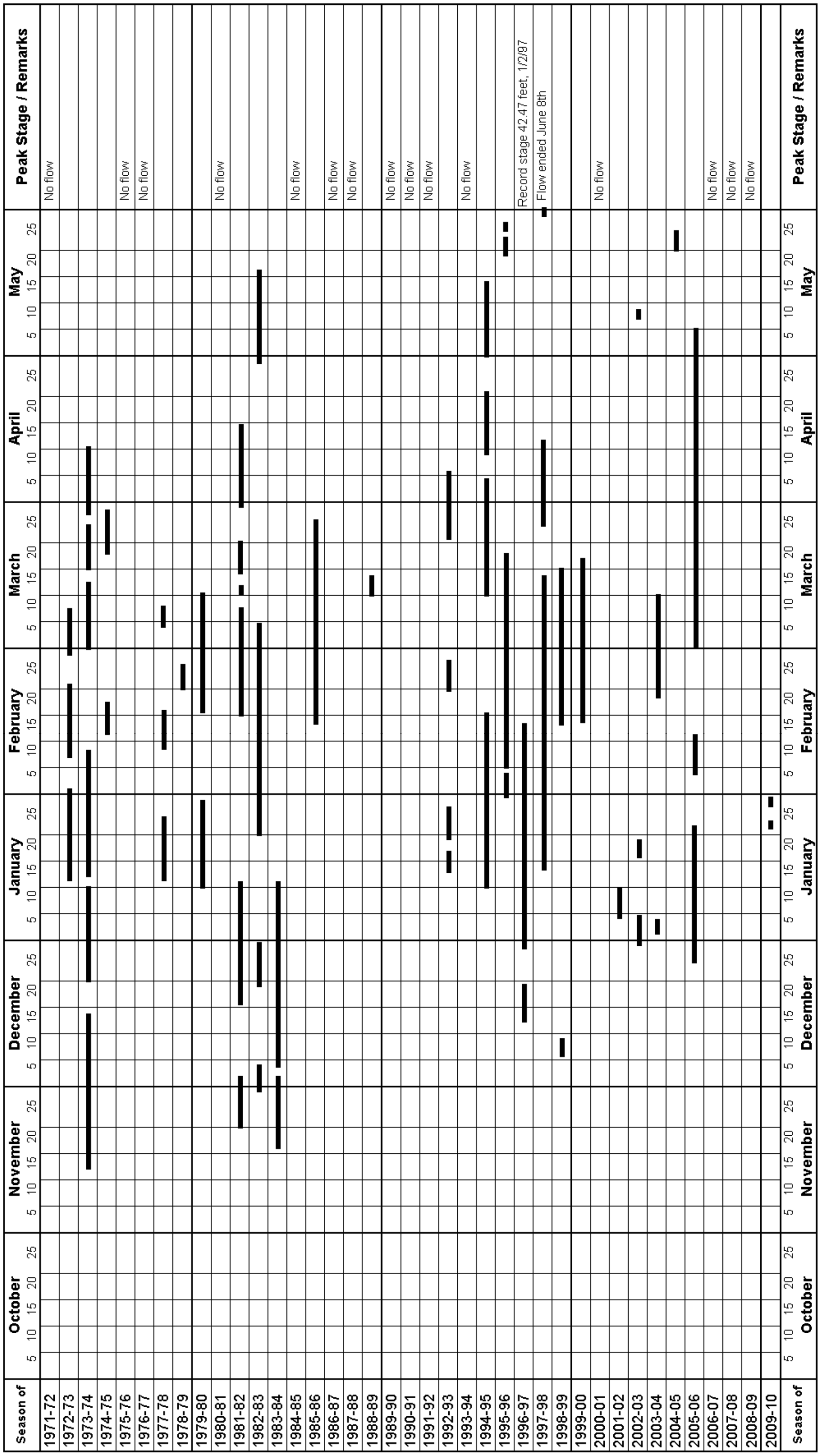
Fremont Weir Overflow Period of Record



Note: Data compiled from records of DWR stream gaging station: Sacramento River at Freemont Weir (FRE), West End

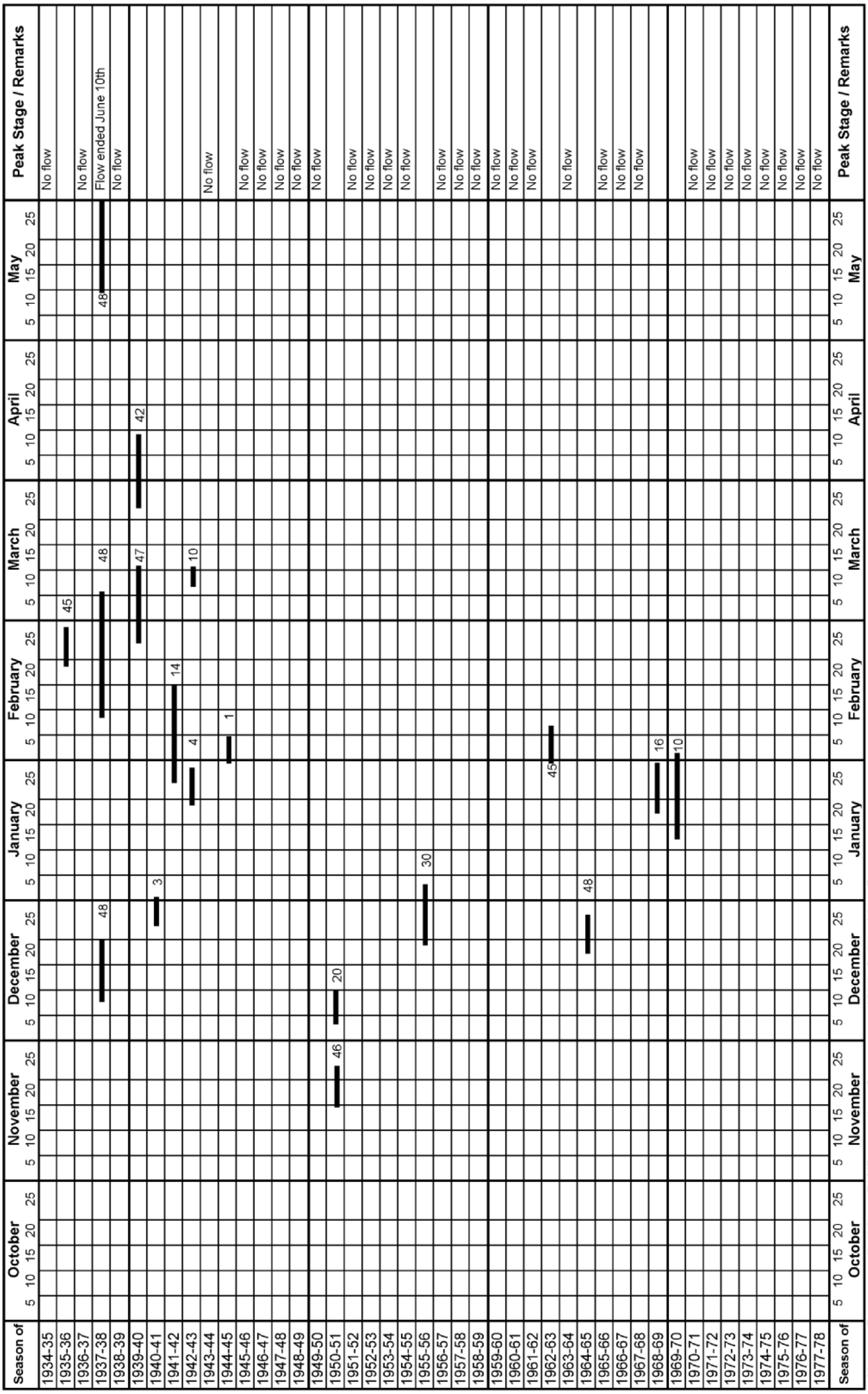
Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 33.50 feet

▬ Designates period of flow over weir

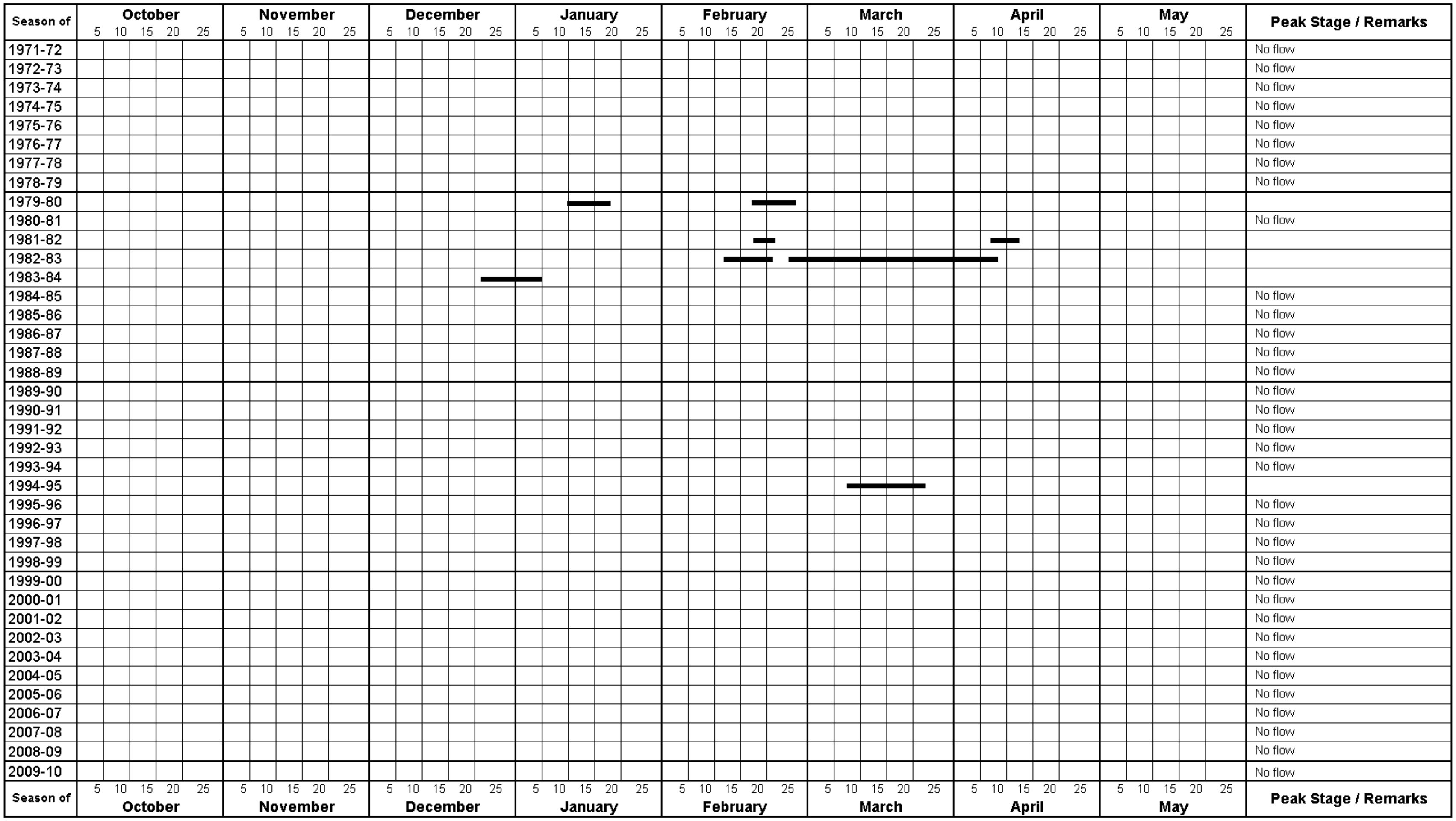


Note: Data compiled from records of DWR stream gaging station: Sacramento River at Freemont Weir (FRE), West End
Datum: 0=0' U.S.E.D.   Period of Record 1935 to 2008   Crest Elevation: 33.50 feet
▬ Designates period of flow over weir

Sacramento Weir Overflow Period of Record



Note: Data compiled from DWR records: Sacramento Weir Spill to Yolo Bypass
Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 24.75 feet Elevation to top of gates: 31.0 feet
▬ Designates period of flow over weir Numeral (1-48) designates number of open gates



Note: Data compiled from DWR records: Sacramento Weir Spill to Yolo Bypass

Datum: 0=0' U.S.E.D. Period of Record 1935 to 2008 Crest Elevation: 24.75 feet Elevation to top of gates: 31.0 feet

▬ Designates period of flow over weir

Sacramento Valley Flood Control Historical Timeline

(Based on *Battling the Inland Sea*, by Robert Kelley)

1849	U.S. Congress passes Swamp Land Act of 1849
1850	Swamp Land Act of 1850
January 7, 1850	City of Sacramento floods
March, 1850	Another storm hits Sacramento. Hardin Bigelow organizes flood fighting party and successfully dams most low points along American and Sacramento Rivers (Bigelow soon becomes Mayor of Sacramento)
1851	First levees built in Sacramento (3-feet high)
December, 1852	First levees built in Sacramento failed
March, 1853	Second flood of season (larger than first) inundates Sacramento
May 31, 1861	AB 54 (State Reclamation Act) passed – Swamplands Commission created, tasked with statewide flood control program development
1861	Andrew Humphreys of the U.S. Army Corps of Engineers (USACE) submits Mississippi River flood study to U.S. Congress – Advocates levees only, main channel flood control approach (All storm flow to remain within levees, and assumption that river will scour out material from the bed to accommodate additional flow)
1862	City of Sacramento Levee District created
March 22, 1866	AB 591 passes – State-wide Swampland Commission dissolved (Reclamation authority delegated to county boards of supervisors)
1867 – 1880	Reclamation districts upstream and downstream of Colusa race each other to construct levees on each bank of Sacramento River
April 13, 1868	Sacramento Valley Levee District 1 (Sutter County) created
May 30, 1868	Green Act (named for *Colusa Sun* editor William S. Green, who authored the bill) passes – Greatly reduces County authority to block reclamation projects. William Green is also the earliest known figure to call for a system of flood overflow basins for the Sacramento River
December 6, 1871	Colusa-area swampland owner, William Parks completes construction of earthen dam across Butte Slough, the effect of which will inundate the property of others upstream

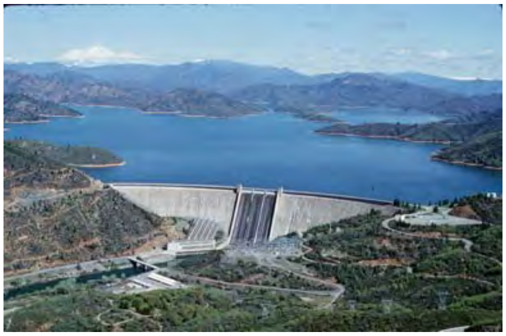
December 27, 1871	Parks Dam is cut by parties unknown; releasing pooled floodwaters downstream – Dam is rebuilt in following year
January 19, 1874	Parks Dam fails
December 28, 1874	L.F. Moulton proxy and Parks Dam flood victim, Justin Laux v. William Parks: Suit is dismissed when Parks purchases Laux's farm
January, 1875	Marysville inundated by water and mining sediment via Yuba River – Mining sediment from hydraulic mining operations had for several years been polluting rivers and settling in river beds, thus raising the bed elevation, and causing more frequent flooding and more extensive damage to adjacent properties
January 25, 1875	Parks Dam fails again
May 7, 1875	William Parks petitions for creation of swampland district
June 3, 1875	County Supervisors deny Parks' request to rebuild dam
June 16, 1875	William Parks' Swampland District (SLD) 226 created – Construction of dam recommences
January 5, 1876	Floodwaters impounded by Parks Dam breach Reclamation District (RD) 70 levee; flooding farm properties downstream
January 8, 1876	Thirty to Forty armed men from RD 70 form naval party to successfully destroy Parks Dam
March 4, 1876	Judge Phil. Keyser issues injunction against Parks' and SLD 226 dam constuction
March, 1878	Drainage Bill enacted – Independent public commission would establish drainage districts; State Engineer would plan projects (based on levees only); Districts would raise and expend taxes, construct and operate projects
March, 1879	Judge Phil. Keyser issues injunction against Bear River mining operations, citing Equity Clause
November, 1879	State Supreme Court overturns Keyser's injunction
January 21, 1880	California's first State Engineer, William Hammond Hall, submits Irrigation/Flood Control Report to State Legislature – A damning report on the mining operations' environmental destruction that advocated State control of drainage
September 26, 1881	Drainage Act declared unconstitutional – Act was not created by State Legislature

January, 1884	Edwards Woodruff v. North Bloomfield Gravel Mining Company-- Prohibited the discharge of mining waste in surface waters
February, 1891	USACE's Biggs Commission Report asserts mining operations may continue, with mining companies construction of debris dams, and Federal restoration of natural river channels downstream
March, 1893	Caminetti Bill (based on Biggs Commission Report findings) signed by President Benjamin Harrison – Establishes California Debris Commission
December, 1894	Marsden Manson & C.E. Grunsky, (consulting engineers working foe State Commissioner of Public Works, A.H. Rose,) issue *Marsden & Grunsky Report for Sacramento Valley Flood Control*, and present it to California Governor – First comprehensive report that advocated bypass channels (William Green had asserted this need three decades earlier)
January, 1896	Flood of '96 – Many mining debris dams (products of Biggs Commission recommendations) fail, sending waste downstream
March, 1896	Rivers and Harbors Act enacted in Congress -- $250K appropriated (none of which was for mining assistance)
May, 1902	River Improvement and Drainage Association of California created
May 11, 1904	San Francisco Chronicle editor and Commonwealth Club founder, Edward Adams' public presentation on statewide flood control and reclamation – A retelling of California reclamation history to date, and a call for State and Federal governments to assert control of future planning
1904	U.S. Army Corps of Engineers' Dabney Commission issues report that rejects the Manson & Grunsky Report's findings of the need for bypass channels and a design flood of 300,000 cfs. Advocates levees only main channel approach and a design flood of 250,000 cfs
March 19, 1907	Flood of '07 – First flood event to occur with USGS staff gages in place to measure river levels – Observed flow calculated to be 600,000 cfs (more than *double* the Dabney design flood) Feather River dumps into Butte Sink, Yuba City & Shanghai Bend Sacramento River jumps banks both north and south of Colusa
1907	USACE's California Debris Commission expands navigation assurance role to include flood control
1909	Flood of '09 – Nearly as large as the Flood of '07
1910	Thomas H. Jackson of the USACE produces the "Jackson Report"; the foundational plan for the Sacramento Flood Control Project – employing the Manson & Grunsky Report's bypass channels, only with a design flood of 600,000 cfs
1911	State Flood Control Act enacted

1913	State Reclamation Board given greater authority
1913	Dredging of the mouth of the Sacramento River begins – Continues through the 1920s
1917	Congress enacts Flood Control Act – Includes funding for the Sacramento Flood Control Project, but largely limited to navigation related tasks
1928	Flood Control Act of ’28 – Enacted as a response to the Mississippi Flood of ’27, and adds flood control to USACE directives
1936	Flood Control Act of ’36 – Promotion of multi-purpose water resource projects for USACE purview
February 11, 1986	Flood of ’86 – 600,000 cfs (maximum design flow) pours into Sacramento-San Joaquin Delta via Sacramento River and Yolo Bypass. Only upstream flood control reservoirs prevent approximately *one million cfs* from severely testing the Sacramento Flood Control Project. As a result, the system largely works as designed
January 3, 1997	Flood of ’97 – nearly 600,000 cfs again pours into Sacramento-San Joaquin Delta via Sacramento River and Yolo Bypass. Only upstream reservoirs prevent approximately one million cfs from inundating the Sacramento Flood Control Project.

Feasibility Investigation of Re-Operation of Shasta and Oroville Reservoirs in Conjunction with Sacramento Valley Groundwater Systems to Augment Water Supply and Environmental Flows in the Sacramento and Feather Rivers

Northern Sacramento Valley Conjunctive Water Management Investigation



Sponsored by
The Natural Heritage Institute
Glenn Colusa Irrigation District

Funded by the
California Department of Water
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Executive Summary

Introduction

In 2006, the Glenn Colusa Irrigation District (GCID) and the Natural Heritage Institute (NHI) jointly embarked on this investigation to explore how the largest water storage reservoir in the Federal Central Valley Project (CVP), Shasta, and the only such reservoir in the State Water Project (SWP), Oroville, could be re-operated in conjunction with northern Sacramento Valley groundwater aquifers to increase water supplies for both environmental and economic uses. GCID is the Sacramento Valley's largest agricultural water supplier with annual water entitlements of 825,000 acre-feet in most years, based on pre-1914 Sacramento River and other water rights. The Natural Heritage Institute (NHI) is a non-governmental, non-profit organization that works at the global scale to preserve and restore the natural functions of river systems and the services they provide to sustain and enrich human life. The investigation was enabled by a combination of state and federal grant funding, including Proposition 50 funding administered by the Department of Water Resources (DWR) and federal funds channeled through the Bureau of Reclamation's (Reclamation) Mid-Pacific Region.

Two other agricultural water suppliers, Western Canal Water District (WCWD) and Richvale Irrigation District (RID), participated in the investigation to the extent of providing technical information and by expressing their interest and potential willingness to support a conjunctive water management project, subject to their review of the investigation's findings. Both districts have water entitlements to Feather River water supplies delivered through the SWP.

Public outreach was conducted in a variety of forums to guide the investigation and to inform interested parties regarding findings and progress. Outreach activities included seven publicly noticed meetings held in the Sacramento Valley, three executive briefings for Reclamation and DWR management staff and four workshops designed primarily to facilitate collaboration with DWR and Reclamation staff involved with operating the CVP and SWP, respectively. Additionally, the project technical team met many times with Reclamation and DWR staff to advance and coordinate the technical work.

At its inception, the investigation focused on the Sacramento Valley's deep aquifers, particularly the Lower Tuscan Formation, which underlies much of the northern portion of the Sacramento Valley. However, as the investigation progressed the study team recognized that such a narrow focus was both overly constraining on the scope of the study and somewhat misleading because it implied that any effects on the aquifer system due to additional recharge or pumping could somehow be confined to a particular portion of the groundwater system. Ultimately the project evaluated the effects of exercising both the northern Sacramento Valley's deep aquifer system, which is presently relatively undeveloped, and the shallower, regional aquifer, which is more heavily pumped for both domestic and agricultural needs.

The investigation began with the expectation that surplus water generated through the re-operation of these reservoirs could be banked in the groundwater aquifers in the Sacramento Valley, like other conjunctive use programs in the San Joaquin Valley of California, with water put into groundwater storage in wet years and extracted in dry years. However, initial assessment and site screening revealed that conditions in the Sacramento Valley are not conducive to this mode of conjunctive management, primarily because groundwater aquifers, although extensively developed and pumped in many areas, mostly for agricultural irrigation, generally recover fully during the precipitation season. What emerged was a conjunctive management approach based on reservoir re-operation backstopped by several options for reducing the draw on reservoir storage when refill is insufficient.

Core Conjunctive Management Concept

The central thesis of this investigation is that most major reservoirs that are operated today for a limited set of water supply and flood control objectives could be re-operated to achieve newly defined ecological restoration benefits while also improving water supply reliability, reducing flood risks, and buffering the effects of climate change. The objective of the project was to explore the potential to optimize operations for all of these benefits without compromising any of them.

Reservoirs that have dual water supply and flood control functions, like the CVP and SWP reservoirs, are typically operated under conservative rules designed to maximize water supply while avoiding flood risks. This results in relative high carryover storage levels but frequent “spills” of water during the refill period to create sufficient flood reservation capacity as necessary to prevent flood damage to the development that has occurred in the downstream floodplain. These spills represent the component of the runoff hydrograph that is not controlled and therefore not appropriated for beneficial use under California water law. To capture and manage this water would require creating additional storage capacity. One way to do that without enlarging the reservoir, or constructing additional ones, is to lower the water storage levels going into the refill period, thereby creating more reservoir capacity to capture high flows. Storage levels can be lowered by delivering additional water from the conservation pool to meet new water supply objectives, including enhancing flows for environmental benefits and augmenting water supplies for consumptive uses such as agriculture.

However, making additional reservoir releases before the ensuing refill period incurs a larger risk of water supply shortages in the event that the quantity of runoff during the refill season, which is always uncertain, is not sufficient to recover the reservoir storage to the level that would have occurred if the additional releases had not been made. Failure for the reservoir to refill would impinge on the reservoir’s function, manifest as water supply shortages, inadequate cold water reserves or reduced carryover storage, or some combination of these factors, unless the reservoir deficit can be made up from other sources.

Three strategies for “paying back[1]” the reservoirs in this manner were investigated:[2]

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[1] The terms reservoir “refill” and reservoir “payback” are used in this report. Reservoir refill refers to recovery of reservoir storage by either capturing surplus surface water flow or by not making reservoir releases that would otherwise need to be made. The latter means of reservoir refill (not making reservoir releases that would otherwise need to be made) is referred to as reservoir payback. Different reservoir payback strategies and mechanisms are described in the report.

[2] A fourth payback strategy that was not considered in this study would be to repay the reservoirs with water conveyed to and banked in aquifers south of the Delta in previous years. This option poses certain advantages to the Sacramento Valley by eliminating or substantially reducing the need to exercise Sacramento Valley aquifers for payback and making surplus water available when and where it has the highest economic value. While, this option is beyond the scope of this phase of investigation, these advantages suggest that it may be a particularly robust alternative that warrants investigation in a subsequent phase of analysis. Notably, this option is only viable if and when additional conveyance capacity through, around or under the Delta becomes available, as is currently being considered in the development of the Bay Delta Conservation Plan (BDCP).

1. Payback from water generated by the project in previous years and stored (or "banked") in aquifers in the Sacramento Valley;

2. Payback from groundwater pumped by cooperating water suppliers served by the CVP or SWP to substitute for water that would otherwise have had to be delivered from the reservoirs; and,

3. Payback from reduction in water demands on the reservoirs, achieved by temporary crop idling on a voluntary, compensated basis.

Project Objectives and Principles

The basic objective of reservoir re-operation is to generate additional water supplies (or "assets") for discretionary uses. In this case, the investigation looked at dedicating additional water supplies generated through re-operation of Shasta and Oroville to two primary in-Valley purposes:

1. **Enhancing ecosystem functions in the Sacramento and Feather Rivers.** Healthy rivers are not just environmentally valuable, they also are central to ensuring reliable, sustainable water supplies. Water supply systems that work in concert with the environment are less likely to be encumbered by court orders, water rights hearings, and other restrictions that can have drastic effects on water supplies for farming and other economic uses.

2. **Improving local water supply reliability, particularly in times of scarcity.** The investigation used historical unmet agricultural water demands to represent the need for additional water supplies in the Valley; however, the additional water supplies could be allocated to other uses and locations.

Design principles were established early on to guide development of project scenarios. The principles were derived in part from public input as well as from the sensibilities of the project sponsors and funding agencies, all aimed at identifying realistic, implementable water management improvements. The primary design principles are as follows:

1. Honor all existing CVP and SWP obligations and operational constraints: The CVP and SWP operate under a complex set of rules and conventions consistent with project water supply and flood control objectives and regulatory requirements, including temperature criteria, State Water Resources Control Board (SWRCB) Decision 1640 (D-1640), and the Central Valley Project Improvement Act (CVPIA). All of these existing objectives and constraints must be observed in any conjunctive management scenario so that water supply obligations to contractors are met to the same extent as under existing operations, and all applicable regulations are satisfied.

2. Achieve net environmental benefits, recognizing that there may be some tradeoffs among different environmental objectives and different times and locations: The Project would be operated to achieve or contribute to achieving certain environmental flow improvements in the mainstem Sacramento and Feather Rivers designed specifically to enhance ecologic functions important to the viability of protected species, particularly Chinook salmon. Three such tradeoffs are acknowledged in the Report:

    - Peak flood control releases, which may be environmentally beneficially, would be captured and released in a controlled pattern to achieve more tailored environmental and geomorphic benefits. In a sense, this is a strategy to use limited environmental water supplies in a more efficient manner.

- When groundwater pumping is needed for reservoir payback (under payback option #2, above), this could result in temporary reductions in base flows in the tributary streams that are also important to protected species.
- More aggressive exercise of the reservoirs to improve flow conditions for ecosystem enhancement may entail a greater risk of depleting cold water reserves needed for downstream temperature maintenance.

Such potential tradeoffs would be addressed through consultation with the listing agencies as part of the NEPA/CEQA compliance by project sponsors. Additional tradeoffs between restoration of more natural river flow regimes and maintenance of cold water pools for river temperature control are also possible and are discussed later in this report.

3. Hold other groundwater users harmless: The participating water districts are legal users of groundwater, and, like all other groundwater users in the basin, enjoy a correlative and co-equal right to increase their groundwater extractions for use by the overlying landowners, subject to the mutual avoidance of harm. Notwithstanding the legality of the participating districts' groundwater withdrawals, the Project would adhere to a "good neighbor" principle and design its mitigation plan to the higher standard of assuring no appreciable, unmitigated harm to existing groundwater users.

4. Generate net economic benefits so that the program can be self-financing: The project must be able to generate revenues that more than offset the expenditures associated with project implementation, including construction, operation, maintenance and any mitigation costs. In the economic analysis conducted for the study, revenues were included only for water sales; no monetary value was attached to ecosystem restoration benefits, although these benefits may be quite appreciable.

Project Site Screening and Selection

A systematic, qualitative assessment of conditions within the Sacramento Valley was conducted to identify particular areas where conjunctive operations appear promising. The team examined fall groundwater elevation maps, water supplier boundaries and distribution system coverages, and water source maps. The project and technical teams developed an initial list of project sites from a review of groundwater maps and their professional knowledge of the Sacramento Valley. Sites were named according to the overlying water districts, though potential sites did not strictly conform to water district boundaries. Information considered in this analysis included the location, water source, existing surface water contracts, current infrastructure and additional infrastructure necessary for delivery of surface water and for extraction of groundwater, operational concepts, and information on existing groundwater conditions. Table ES-1 summarizes this information considered for the nine initial sites.

Evaluation of existing groundwater conditions within the Sacramento Valley shaped the site screening and selection. In general, the evaluation revealed that while groundwater levels are drawn down during the irrigation season in many areas of the basin, levels recover during the precipitation season except during prolonged (multi-year) dry periods. Cones of depression generally do not persist over the

TABLE ES-1
Initial Project Sites and Parameters
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Location	Water Source	Site Type	Annual Surface Water Contract	Project to Integrate With	Currently Integrated?
Butte Basin	Surface	GW Pumping	~ 300 TAF/yr	SWP	Yes
Orland-Artois WD	Mixed	Both	53 TAF/yr	CVP	Yes
Rancho Capay WD	Ground	GW Banking	None	CVP	No
Corning Canal Area	Mixed	Both	33 TAF/yr	CVP	Yes
Yolo-Zamora WD	Ground	GW Banking	None	CVP	No
Glenn-Colusa ID	Surface	GW Pumping	825 TAF/yr	CVP	Yes
Stony Creek Fan area	Surface	GW Pumping	~ 100 TAF/yr	Orland	No
Colusa County WD	Mixed	Both	68 TAF/yr	CVP	Yes
Olive Percy Davis Ranch	Surface	GW Pumping	32 TAF/yr	CVP	Yes

multiple years necessary to make the dewatered aquifer space suitable for banking[3]. Any additional water recharge induces additional groundwater discharge to the streams. The conclusion from this analysis was that conjunctive operations based on a groundwater banking payback mechanism are not feasible in the Sacramento Valley at this time. Thus, further effort was concentrated on a second option for a payback mechanism: pumping groundwater in lieu of making reservoir deliveries in years when reservoir payback would be necessary.

Two sites were identified on which to conduct more refined analyses with surface and groundwater modeling tools. The GCID and Butte Basin Projects[4], supplied by the CVP and SWP, respectively, provided the potential to pump the largest quantity of groundwater compared to other sites, and are already well integrated with the surface water system. Under this option, conjunctive management operations would utilize wells within GCID and the Butte Basin as a backstop for more aggressive operation of Shasta Reservoir and Oroville Reservoir, respectively.

Ecological Flow and Agricultural Water Supply Targets for Conjunctive Operations

A major element of this investigation was the development of specific ecological flow objectives for the Sacramento and Feather Rivers to use to formulate and evaluate reservoir re-operation scenarios. The ecologic flow objectives fall into two categories, three that were designed for Chinook salmon recovery, and one that was designed for riparian habitat recovery. These may be summarized as follows:

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[3] Based on the most recent (Fall 2011) data collected by DWR, there appear to be some areas in the northern Sacramento Valley with persistent groundwater level declines, primarily in Glenn and Tehama Counties. These areas should be evaluated for potential groundwater banking operations in future work phases.

[4] The major water surface water suppliers within the Butte Basin are WCWD, RID and Biggs-West Gridley Water District (BWGWD). BWGWD declined to participate in the investigation, so development of the Butte Basin project concentrated on the other two districts. It is noted that WCWD and RID were passive project participants meaning they provided information for the investigation but did not assume a sponsorship role. Additionally, the Stony Creek Fan area and Orland Project was identified as a third potential project. However, upon further evaluation into potential groundwater pumping capacities and the ability to integrate the project with the Sacramento River system, it was determined that this project would not be investigated during this phase of the project. However, this project does deserve additional analysis in future phases of investigation.

For Chinook salmon:

- Geomorphic objectives: Sediment transport, bed mobilization and bed scour; channel migration and floodplain processes; inundation and fine sediment deposition
- Floodplain inundation objectives : inundated floodplain habitat for rearing juveniles during the later winter and early spring; maintain and recruit spawning habitat, but avoid scouring gravels while eggs or alevon are present
- Spring pulse flow objectives: Suitable flow conditions and temperatures for all life stages;

For Riparian Habitat:

- Fremont cottonwood seedbed preparation, seed germination and seedling growth; periodic large-scale disturbance of the riparian zone; riparian stand structure and diversity

In each category, the objectives are expressed as quantitative flow targets for the two rivers, respectively, defined in terms of flow magnitude, duration, frequency and seasonality, by river reach[5]. The various objectives are coupled with a dynamic decision system for prioritizing objectives from year to year.

Historical agricultural water supply shortages in the Sacramento Valley were used to represent the targets for water supply enhancements. Specifically, for the CVP/Sacramento River, unmet demands of CVP contractors within the Tehama-Colusa Canal Authority (TCCA) were used to represent additional demands. Members of the TCCA, including contractors supplied from the Corning Canal, hold agricultural service contracts for approximately 320 TAF of contract supply from the CVP, subject to shortages. Historical shortages (as simulated in CalSim II) were used to quantify unmet demands. On the Feather River system, the majority of SWP contractors have reliable water supplies with the exception of a few small contractors. There are no existing SWP contractors with large, frequently unmet agricultural demands in the Butte Basin. Therefore a more general unmet agricultural demand was defined for the Feather River based on user input and judgment.

Initial Project Scenarios

Four conjunctive operations scenarios were developed for the GCID and Butte Basin project locations for initial analysis. The scenarios are differentiated primarily by the following two parameters:

- Maximum Payback Capacity. This is the maximum volume of groundwater pumping that would occur in any year within the pumping period (see below) in GCID and the Butte Basin, respectively. This capacity essentially establishes the scale of the conjunctive operation, since the water deficit in the reservoirs cannot exceed the capacity to repay it, when that becomes necessary. Maximum capacities were based primarily on professional judgment taking into consideration historical pumping in the two areas and average pumping intensity (acre-feet per acre). The payback capacities selected for analysis were:
    - 100 TAF in GCID and 50 TAF in Butte Basin; total 150 TAF

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[5] Although developed specifically for the purpose of formulating conjunctive management strategies, the recommended objectives and flows are believed to have broader utility beyond this investigation.

  - 200 TAF in GCID and 100 TAF in Butte Basin; total 300 TAF

- Pumping Period. Pumping must occur when there is a demand for water that would otherwise be satisfied by reservoir releases. In both project areas, the dominant crop is rice, which is typically planted between mid-April and early June and harvested in September. Following harvest, most rice fields are re-flooded between September and November for rice straw decomposition and to create waterfowl habitat. Thus the water delivery season in both areas is from mid-April through November. Based on this, three pumping periods listed below were identified for analysis. Different pumping periods were evaluated primarily to reveal differences in aquifer response to differences in the timing and rate of pumping. Additionally, the pumping period affects the capital investment needed for pumping facilities.
  - “Summer” defined as May through August
  - “Fall” defined as September through November
  - “Summer and Fall” defined as May through November

The combinations of payback capacity and pumping periods selected to form scenarios are listed in Table ES-2.

TABLE ES-2
Project Scenarios Evaluated
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Scenario	GCID Annual Pumping Capacity	Butte Basin Annual Pumping Capacity	Pumping Season
1	100 TAF	50 TAF	Summer (May through August)
2	200 TAF	100 TAF	Summer (May through August)
3	100 TAF	50 TAF	Fall (September through November)
4	100 TAF	50 TAF	Summer and Fall (May through November)

TAF = thousand acre-feet

Additionally, two well field configurations were evaluated for each scenario, one corresponding to existing wells screened at depths between 100 to 500 feet and a second well field corresponding to new wells screened at depths of 900 to 1,100 feet. Thus a total of eight operational scenarios were evaluated.

Analytic Tools

Formulating and evaluating potential conjunctive management projects requires simulation of both surface water and groundwater systems. Simulating the surface water system is necessary to determine when water is available to refill reservoirs and to estimate unmet agricultural demands, environmental objectives, and flow conditions. A groundwater model is necessary to estimate the effects of additional pumping on aquifer systems, including the spatial extent and magnitude of drawdown and potential change in stream-aquifer interaction. Changes in stream-aquifer interactions may affect the surface water system, depending on stream conditions when the changes occur. For example, if additional pumping results in more stream loss to the aquifer or less aquifer contribution to stream flow during the winter season of relatively wet years when the surface water system has surplus flow, there may be little or no impact. However, if pumping reduces stream flow during months and years when the surface water system is being operated to meet specific flow or water quality requirements, any reduction in stream flow will require a corresponding increase in reservoir release to ensure the flow requirement continues to be met. This decreases the water supply benefit of conjunctive management projects.

Evaluating this aspect of conjunctive management projects required coordinated operation of surface water and groundwater models.

The main tool used to evaluate alternative conjunctive management operations strategies and test alternative environmental flow thresholds and priorities was a spreadsheet-based surface water model. The model simulates changes in operation of Lake Shasta and Lake Oroville relative to conditions depicted in a baseline CalSim II simulation of CVP and SWP operations. The CalSim II baseline provides time series of reservoir storage levels, stream flows, and water deliveries which are used by the surface water model. Conjunctive management operations are simulated and layered onto baseline operations based on user inputs, while maintaining compliance with existing CVP and SWP rules, regulation, and operations. Consistent with currently available CALSIM II runs, the surface water model operates over the 82-year period from 1922 through 2003, inclusive.

For the groundwater analysis, an existing simplified groundwater modeling tool was completely re-designed and improved, to yield a powerful analytical package now referred to as the Sacramento Valley Groundwater Model (SACFEM). SACFEM is a full water budget based transient groundwater flow model that incorporates all of the groundwater and surface water budget components on a monthly time step over the period of simulation. The model domain covers the entire Sacramento Valley floor from Redding in the north to Sacramento in the south, and includes explicit representations of all major and many minor streams. The model provides very high resolution estimates of groundwater level and streamflow effects due to conjunctive water management pumping. In contrast to the surface water model, the groundwater model operates over a 17-year period from 1987 to 2003, due to the lack of historical data needed to calibrate the model prior to 1987.

Performance of Initial Project Scenarios

The performance of the initial project scenarios was evaluated by simulating operations with the surface water model. Scenarios 1, 3 and 4 are identical from a surface water operations perspective because they have the same payback pumping capacity in GCID and in the Butte Basin, respectively. Scenario 2 is different because GCID and Butte Basin pumping capacities are higher compared to Scenarios 1, 3 and 4.

The project benefits in terms of environmental flow targets met and agricultural water supplies generated are presented in Table ES-3. In GCID, at the 100 TAF project scale (associated with Scenarios 1, 3 and 4), environmental flow releases are made in 23 years in the 82 year period of analysis, or 28 percent of the years. The average environmental release volume is 46 TAF in the years made, or 13 TAF averaged over the full 82-year period. Agricultural water supply releases were made in 24 years, or 29 percent of the years, with the average release volume being 46 TAF in the years made and 14 TAF averaged over the full 82-year period. When the GCID project scale is doubled to 200 TAF (Scenario 2), project benefits increase appreciably. Environmental flow releases are made in 40 years, or 49 percent of the time, with the average release being 96 TAF in the years of occurrence and the 82-year average being 47 TAF. Agricultural water supply releases also increase but not by as much proportionally as environmental releases. The frequency of agricultural releases stays the same (at 24 years), but the average release increases to 75 TAF in the years of occurrence and 22TAF over the 82-year period.

In Butte Basin, at the 50 TAF project scale (associated with Scenarios 1, 3 and 4), environmental flow releases are made in 28 years in the 82 year period of analysis, or 34 percent of the years. The average environmental release volume is 21 TAF in the years made, or 7 TAF averaged over the full 82-year period. Agricultural water supply releases were made in 30 years, or 37 percent of the years, with the average release volume being 27 TAF in the years made and 10 TAF averaged over the full 82-year

TABLE ES-3
Environmental and Agricultural Water Supply Benefits under Conjunctive Operations
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Scenario(s)	Project/System	Payback Pumping Capacity (TAF)	Environmental Benefits			Agricultural Benefits		
			Number of Years	Avg in Yrs of Occurrence (TAF)	Avg Over All Yrs (TAF)	No. Yrs.	Avg in Yrs of Occurrence (TAF)	Avg Over All Yrs (TAF)
1, 3 and 4	GCID/CVP Lake Shasta-Sac R	100	23	46	13	24	46	14
1, 3 and 4	Butte Basin/SWP Lake Oroville-Feather R	50	28	21	7	30	27	10
2	GCID/CVP Lake Shasta-Sac R	200	40	96	47	24	75	22
2	Butte Basin/SWP Lake Oroville-Feather R	100	44	43	23	30	52	20

period. When the Butte Basin project scale is doubled to 100 TAF (Scenario 2), project benefits increase appreciably. Environmental flow releases are made in 44 years, or 54 percent of the time, with the average release being 43 TAF in the years of occurrence and the 82-year average being 23 TAF. Agricultural water supply releases also increase but not by as much proportionally as environmental releases. The frequency of agricultural releases stays the same (at 30 years), but the average release increases to 52 TAF in the years of occurrence and 20TAF over the 82-year period.

A fundamentally important finding is revealed through inspection of how the reservoirs are refilled following draw down to make project releases (Table ES-4). For the GCID 100 TAF project scale (Scenarios 1, 3 and 4), reservoir refill occurs in 33 years. But in 29 years the refill comes from surplus surface flows. In only 4 years is it necessary to pump from project groundwater. That is less than 5 percent of the years of operation. The average refill from surplus surface flows is 70 TAF in the years of occurrence and 24 TAF over the full period. In contrast, the refill from project groundwater pumping is also 70 TAF in the years of occurrence but just 4 TAF annually averaged over the full period. Importantly, the maximum year pumping is 98 TAF or nearly the full assumed repayment pumping capacity. At the 200 TAF project scale in GCID (Scenario 2), reservoir refill occurs in 41 years, with refill from surplus surface water occurring in 35 years and from project groundwater pumping in 6 years. The average refill from surplus surface flows is 139 TAF in the years of occurrence and 58 TAF annually over the full period.

For the Butte Basin 50 TAF project scale (Scenarios 1, 3 and 4), reservoir refill occurs in 43 years, including 37 years of refill from surplus surface flows and just 6 years from project groundwater pumping. The average refill from surplus surface flows is 32 TAF in the years of occurrence and 14 TAF over the full period. In contrast, the refill from project groundwater pumping is 44 TAF in the years of occurrence but just 3 TAF annually averaged over the full period. Importantly, the maximum year pumping is 50 TAF, the full assumed repayment pumping capacity. At the 100 TAF project scale in Butte Basin (Scenario 2), reservoir refill occurs in 51 years, with refill from surplus surface water occurring in 43 years and from project groundwater pumping in 8 years. The average refill from surplus surface flows is 72 TAF in the years of occurrence and 36 TAF annually over the full period.

TABLE ES-4
Reservoir Refill under Conjunctive Operations
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

			Surplus Surface Water			Project Groundwater Pumping			
Scenario(s)	Project/System	Payback Pumping Capacity (TAF)	Number of Years	Avg in Yrs of Occurrence (TAF)	Avg Over All Yrs (TAF)	No. Yrs.	Avg in Yrs of Occurrence (TAF)	Avg Over All Yrs (TAF)	Maximum Year (TAF)
1, 3 and 4	GCID/CVP Lake Shasta-Sac R	100	29	70	24	4	70	4	98
1, 3 and 4	Butte Basin/SWP Lake Oroville-Feather R	50	37	32	14	6	44	3	50
2	GCID/CVP Lake Shasta-Sac R	200	35	139	58	6	123	9	198
2	Butte Basin/SWP Lake Oroville-Feather R	100	43	72	36	8	75	7	100

For the Butte Basin 50 TAF project scale (Scenarios 1, 3 and 4), reservoir refill occurs in 43 years, including 37 years of refill from surplus surface flows and just 6 years from project groundwater pumping. The average refill from surplus surface flows is 32 TAF in the years of occurrence and 14 TAF over the full period. In contrast, the refill from project groundwater pumping is 44 TAF in the years of occurrence but just 3 TAF annually averaged over the full period. Importantly, the maximum year pumping is 50 TAF, the full assumed repayment pumping capacity. At the 100 TAF project scale in Butte Basin (Scenario 2), reservoir refill occurs in 51 years, with refill from surplus surface water occurring in 43 years and from project groundwater pumping in 8 years. The average refill from surplus surface flows is 72 TAF in the years of occurrence and 36 TAF annually over the full period.

It is evident from this summary that there are opportunities to generate appreciable incremental benefits through conjunctive operations in terms of increased environmental flow releases and agricultural water supplies, without infringing on CVP and SWP operations. Additional results from operations simulations are described in the body of this report.

Impacts of Project Groundwater Pumping

Impacts to Existing Groundwater Pumpers

The effects of the additional project groundwater pumping for reservoir payback were evaluated using the groundwater model. This was done by imposing the payback pumping monthly time series determined by the surface water model on baseline pumping to estimate the effects on groundwater levels. The effects of changes in groundwater levels on the operability of existing wells in the project area and on pumping costs were then evaluated.

There are approximately 15,400 existing groundwater production wells in the project area, with about 9,100 of those wells (59%) being relatively shallow, domestic supply wells and about 4,500 wells (29%) being irrigation wells. The remaining wells are for unknown or other purposes (Table ES-5).

TABLE ES-5
Number of Water Supply Wells in Project Area[6]
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Use	**Number of wells**
Domestic	9,058
Irrigation	4,455
Unknown[7]	1,388
Other	267
Municipal	139
Stock	75
Public	52
Total	15,434

The surface model predicted the need for pumping in about 10 percent of the years in the Butte Basin and about 7 percent of the years in GCID under the 300 TAF pumping scenarios (200 TAF GCID, 100 TAF Butte Basin; see Table ES-6). In years in which pumping occurs, pumping is usually required in either GCID or in the Butte Basin, but not both. However, in exceptionally dry years, pumping would occur in both areas in the same year (see bolded years in Table ES-6).

TABLE ES-6
Occurrence of Pumping
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Maximum Pumping	Number of times pumping occurs (82 years of record)		Years in which pumping occurs		Number of times pumping occurs in GCID and/or Butte Basin
	GCID - Shasta	Butte - Oroville	GCID - Shasta	Butte - Oroville	
150 TAF (100 TAF GCID; 50 TAF Butte Basin)	4	6	1947, 1987, 1988, **1990**	1933, 1961, **1990**, 1992, 1994, 2002	9
300 TAF (200 TAF GCID;100 TAF Butte Basin)	6	8	1923, **1929**, **1947**, 1987, 1988, **1990**	**1929**, 1933, **1947**, 1961, **1990**, 1992, 1994, 2002	11

* **bolded** years indicate that pumping would have occurred in both GCID and Butte Basin under the Project.

The additional (or interference) drawdown in the shallow aquifer caused by project pumping is shown in Table ES-7, indicating that the maximum additional drawdown is generally less than 10 feet and the average is generally less than one foot. Maximum drawdown occurs near project pumping wells but dissipates rapidly moving away from wells.

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[6] Data provided by California Department of Water Resources Northern District Office. 2009.

[7] May include monitoring wells, vapor recovery wells, or other wells not constructed for water supply purposes.

TABLE ES-7
Summary Statistics of Monthly Average Interference Drawdown in the Shallow Aquifer by Pumping Scenario, 1987 – 2003
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	Interference Drawdown (ft)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	0.0	13.6	0.5	0.3	0.7
300 TAF Summer Pumping, Existing Well Field	0.0	8.3	0.4	0.2	0.6
150 TAF Summer Pumping, New Well Field	0.0	6.2	0.3	0.2	0.4
150 TAF Summer Pumping, Existing Well Field	0.0	5.4	0.3	0.2	0.4
150 TAF Fall Pumping, New Well Field	0.0	7.0	0.4	0.2	0.4
150 TAF Fall Pumping, Existing Well Field	0.0	6.1	0.4	0.2	0.5
150 TAF Summer & Fall Pumping, New Well Field	0.0	5.9	0.4	0.2	0.4
150 TAF Summer & Fall Pumping, Existing Well Field	0.0	5.0	0.4	0.2	0.5

Based in the interference drawdown simulated by the groundwater model, the results of the analysis of impacts to existing groundwater users are summarized as follows:

- The operability of some domestic wells is likely to be affected because these wells tend to be shallow and the magnitude of interference drawdown caused by project pumping is significant relative to the screened intervals of these wells. The maximum number of domestic wells impacted is estimated to be between 153 and 284, which is a relatively small percentage (about 3%) of the total number of domestic wells. This impact occurs in 1990 when pumping occurs in both GCID and the Butte Basin and may be overstated to the extent that some of the impacted wells are no longer in operation. It is noted that goal in project implementation would be to minimize or avoid impacts to domestic wells, if possible.

- Impacts to the operability and yields of existing irrigation wells are negligible because the magnitude of interference drawdown from project pumping is small relative to the screened intervals of these wells.

- Energy requirements and costs will be increased for both domestic and irrigation pumping due to increased pumping lifts. On an annualized basis, the increased energy cost for irrigation pumping is estimated to range between $123,000 and $228,000, and for domestic pumping is estimated to range between $3,000 and $5,000.

Impacts on Streamflow

The modeled project pumping scenarios result in some streamflow reductions, due either to increased stream loss to aquifers or decreased aquifer flow into streams (Table ES-8). To compensate for these losses, the modeling incorporated releases from Shasta and Oroville when the system is “in balance.” Although these releases help maintain streamflow in the Sacramento and Feather Rivers, while insuring the system as whole doesn’t experience significant losses, the releases do not directly mitigate the impact of *tributary* streamflow losses to ecosystems and species. As a starting point for the assessing impact to tributary streams, the project analyzed Butte Creek due to its high ecosystem value combined with some of the largest discharge losses due to pumping. An additional consideration is that historical streamflow records are available for Butte Creek but generally not for other smaller streams.

TABLE ES-8
Peak Effects on Streamflow from Conjunctive Management Operations
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	Scenario 1		**Scenario 2**		**Scenario 3**		**Scenario 4**	
Stream	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**
All Streams[a]	54	53	111	105	80	90	64	65
Butte Creek	13	12	72	69	50	48	39	33
Sacramento River – GCID to Wilkins Slough	42	37	32	28	16	18	16	15
Feather River	3	3	6	6	4	4	4	4
Little Chico Creek	3	3	6	5	4	3	4	3
Salt River	1	5	5	8	2	5	2	5
Stone Coral Creek	6	9	11	15	7	10	6	9
Stony Creek	4	5	7	7	4	6	4	4

[a] Includes the 7 streams listed below.

The Butte Creek analysis yielded the following key results:

- Project pumping will not impact the uppermost reach in the project areas, the primary spawning area for Spring-run Chinook and Central Valley steelhead
- Pumping will have a greater impact on the lower reaches of Butte Creek, than the upper
    - In addition to cumulative effects, the *rate* of leakage is higher in downstream reaches
- The largest absolute losses in streamflow occur when discharge is also highest (Jan.-Mar)
    - The magnitude of impacts in relation to the baseflow at this time is not substantial (maximum of 1-3% loss in streamflow)
- The largest percentage loss in stream flow occurs in the lowest reach during summer/ early fall when Spring-run have already migrated upstream and steelhead are only beginning to enter the streams
- Project pumping never causes average monthly discharge to fall below the instream flow standards in the four upstream reaches
- June average monthly discharge in the lowermost reach, falls below the 40 cfs instream standard twice in the 17 year record due to pumping of up to 150K, and four times under pumping of up to 300K
    - Most Spring-run migration has already occurred by June, but some late Spring-run migrants, may experience minimal impacts
    - These impacts occur during the drought years of 1990, 1991, 1992, 1994, when Butte County irrigators participated in the drought water bank

The results of the analysis do not reveal any significant negative impact to Spring-run Chinook or Central Valley Steelhead in Butte Creek due to project pumping. Furthermore, this analysis focused only on those years with stream impacts (water years 1987 - 2003), during which time groundwater would have been pumped more frequently than over the entire period assessed by the surface water model (1922-2003). As such, on average impacts would likely be less significant and rarer than those projected in this analysis.

Economic Analysis

The economic analysis did not assign a monetary value to the environmental benefits that would accrue. This was not because these would be negligible. In fact, the potential increase in salmon productivity could be quite substantial. Rather, the economic analysis was conducted in part to determine whether the revenue from the project's potential water sales alone would be large enough to pay for the capital and operational costs. In sum, the question was not whether the project would be worthwhile, but whether it could pay for itself.

The net benefit of the project considering the associated costs and expected benefits varies depending primarily on where the water generated by the project can be sold and, to some extent, on whether new wells are constructed or the project is operated using primarily existing wells. As summarized in Table ES-9, if the water generated through conjunctive operations is sold in the Sacramento Valley, only one of the scenarios has a positive net benefit, with the others having modest to strong negative net benefits. In contrast, if the water were valued at rates paid in ag sectors outside the Sacramento Valley or by urban customers, only one of the scenarios has a negative net benefit with the others being positive. Interestingly, even though the 150 TAF summer and fall pumping using the existing wells was the least-cost scenario, the analysis demonstrates that the largest net benefit is associated with the 300 TAF summer pumping scenario using the existing wells (if the water could be exported south of the Delta).

It can be seen from Table ES-9 that the existing well scenarios dominate the new well scenarios in terms of net benefits. The high capital costs associated with constructing new wells make this option less economically viable.

TABLE ES-9
Net Benefit under Various Pumping Scenarios
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Scenario	Annual benefits, local use ($M)	Annual benefits, exports ($M)	Total Cost (PV, $M)	Net benefits, local use ($M)	Net benefits, export ($M)
1 300 TAF Summer New Wells	183	365	290	-107	76
2 300 TAF Summer Existing Wells	183	365	212	-30	153
3 150 TAF Summer New Wells	73	145	135	-62	11
4 150 TAF Summer Existing Wells	73	145	94	-21	52
5 150 TAF Fall New Wells	74	148	210	-136	-62
6 150 TAF Fall Existing Wells	74	148	144	-70	4
7 150 TAF Summer & Fall New Wells	73	147	88	-14	59
8 150 TAF Summer & Fall Existing Wells	73	147	65	8	81

Operational and Analytic Refinements Recommended by Project Operators

Beginning in April 2010, a series of three ½-day workshops were held with a select group of CVP and SWP operators for the purpose of refining project scenarios. The main purposes were: (1) to identify additional project purposes and benefits that could potentially be realized through conjunctive operations as a means of enhancing project economic performance and (2) to ensure that the simulations were as realistic as possible. The workshops were complemented with one-on-one consultations between operators and project team members as needed to clarify comments and develop specific recommendations for incorporation into scenario development and the supporting modeling methodology.

Specific refinements identified through collaboration with the project operators included the following:

- Updated CALSIM II Baseline. The CALSIM II baseline used for the initial modeling pre-dated the 2008 Biological Opinion on delta smelt (smelt BO) and the 2009 Biological Opinion on Chinook salmon (salmon BO). The baseline was updated with a CALSIM II model run with the smelt BO and salmon BO included. This baseline was used for further development and evaluation of project scenarios.

- Shasta and Oroville Reservoir Minimum Release Constraints. CVP operators expressed concerns about the ability to reduce Shasta releases under conditions when releases are driven by temperature compliance in the Sacramento River below the reservoir rather than water supply demands further downstream. Constraints on the ability to reduce Shasta releases were specified in the form of monthly minimum Keswick releases for temperature compliance. Constraints on the ability to reduce Oroville releases for temperature compliance were specified by SWP operators as a function of Oroville releases and time of year. Potential reductions ranged from zero to 1,000 cfs.

- Forecast-Based Operations. The initial surface water model made project asset decisions (volume of additional reservoir release) based on a perfect forecast of September reservoir storage. The implication of this assumption was to minimize the risk of achieving targeted levels of carryover storage due to conjunctive operations. The surface water model was refined to include a forecast of fall storage conditions based on current reservoir storage, runoff forecasts, and an estimate of reservoir releases from the current month through September. This change made the simulations more like actual project operations.

- Oroville Reservoir Carryover Storage Targets. SWP operators specified Oroville storage targets for the purpose of increasing carryover storage when at or below 1.5 million acre-feet (MAF) under base conditions by up to a maximum of 200 thousand acre-feet (TAF). These targets were developed to assist in mitigating effects of damage to the low-elevation outlet that occurred during gate testing several years ago. Damage to the low-elevation outlet has effectively increased dead storage in Lake Oroville leading to a desire to increase carryover storage.

- Crop Idling for Reservoir Payback. The surface water model was modified to simulate crop idling as a payback mechanism to recover reservoir storage. This was done to reduce or avoid the need for project pumping, thereby reducing project costs and enhancing overall project cost-effectiveness. A number of assumptions and constraints were placed on crop idling operations, the main assumptions being that crop idling would be voluntary and incentive-driven and would be limited in extent to no more than 20% of the irrigated area in GCID and the Butte Basin (WCWD and RID).

With these refinements made to the surface water model and project operating objectives and constraints, the project scenarios were reassessed, leading to the following observations:

- Updating the CALSIM II baseline to include the smelt and salmon BOs had negligible effect on project performance.

- The addition of forecast-based operations together with minimum reservoir releases for water temperature compliance dramatically reduced project performance with respect to generating environmental flow releases and agricultural water supplies. Relative to initial conditions, benefits were reduced by one-half to two-thirds. The procedures developed for forecasting end-of-year reservoir storage were deliberately conservative to limit risks to carryover storage; however, the effect of the forecasts was to substantially reduce the estimated project water assets, which severely reduced both environmental flow releases and agricultural water supplies. The effect of minimum reservoir releases was to reduce the times when payback pumping can effectively recover reservoir levels, also diminishing project performance.

- Employing project pumping to assist in meeting Oroville Reservoir carryover targets is not effective because project pumping is called on frequently, to the extent that groundwater impacts could become problematic. Additionally, much of the water held in reservoir storage subsequently spills due to displacement with by surplus surface flows.

- Temporary crop idling is not an effective means of reservoir payback, primarily because crop idling decisions need to be made early in the season and involve making an irreversible commitment to participating growers for purchasing the water generated through crop idling regardless of whether the water can be held in upstream storage or put to beneficial use downstream. Modeling shows that too frequently temperature releases govern reservoir operations and the water generated by crop idling cannot be held in storage.

Fundamental Conclusions

The seminal conclusion of this investigation is that re-operating Shasta and Oroville Reservoirs in conjunction with operation of Sacramento Valley groundwater aquifers could produce appreciable additional water supplies for discretionary allocation to environmental enhancement flows in the Sacramento and Feather Rivers, for increased local and regional water supply reliability and potentially for meeting water demands outside the Sacramento Valley. This can be done with low risk to CVP and SWP reservoir storage levels and water deliveries under most conditions because additional releases made for these purposes are replaced with reservoir refill from surplus surface flows most of the time, with groundwater pumping for reservoir “payback” required relatively infrequently. In the years needed, groundwater pumping would be appreciable but potential impacts to existing Sacramento Valley groundwater conditions in the areas of pumping appear be manageable and could be mitigated. Overall, the project would result in a net gain of groundwater storage in the Sacramento Valley if, as assumed, additional water supplies generated by re-operation are used to meet demands that would otherwise be met by pumping groundwater.

Modeling of conjunctive operations reveals that the ability to recover reservoirs by pumping groundwater when they fail to recover sufficiently from surplus surface flows is constrained at times by the need to sustain reservoir releases for temperature control, in order to provide desirable conditions for salmonids. In effect, the scale of conjunctive operations and the ability to generate one kind of environmental benefits (ecologic flows) is constrained by existing operational requirements for another kind of environmental benefits (temperature control). This tradeoff between different environmental water uses points to the need for comprehensive, holistic approaches to environmental water management. The analytical tools developed for this project are sufficient to support development of such approaches.

While an economically feasible in-Valley operation scenario was not identified by the investigation, prospects of a viable formulation appear promising and further development and integration of the core concept is warranted, particularly if greater revenues can be derived by selling water at higher prices, or there was a willingness to pay for the environmental benefits provided. It is noted that the ecologic benefits that could be achieved by improving flow regimes in the Feather and Sacramento Rivers through conjunctive operations were not included in the assessment of the project's economic feasibility. This is because methodologies for valuing those benefits are somewhat speculative. Additionally, the benefits that would result from improved groundwater conditions within the Sacramento Valley due to the delivery of additional surface water supplies and consequent relaxation of groundwater pumping were not factored into the economic analysis. Valuation and inclusion of these benefits in any future phases of investigation would enhance the economic feasibility of conjunctive operations.

Recommended Further Investigation

A number of specific recommendations for further development and refinement of Sacramento Valley conjunctive water management are provided in the body of this final report. These are primarily technical in nature, involving reconciling tradeoffs among different types of environmental water uses, more detailed water temperature modeling, refined reservoir payback operations, integration with south of Delta groundwater banking and refinement of analytic tools.

Beyond the technical factors lie significant institutional and social challenges that would need to be addressed if there is sufficient interest in advancing the project toward implementation. These include developing protocols and procedures for real-time operations decisionmaking, integrating conjunctive operations into the Coordinated Operations Agreement, developing project governance structures among local political jurisdictions, and developing formulae for allocating project benefits and costs.

However daunting these challenges may appear, the potential benefits relative to risks revealed through this investigation suggest that further efforts to develop and implement conjunctive water management in the Sacramento Valley are warranted.

1. Principal Findings and Conclusions

The main findings and conclusions reached through this investigation are summarized below:

1. The core concept of augmenting yield from Lake Shasta and Lake Oroville by increasing releases before the refill season, and thereby reducing carry-over storage levels to allow subsequent capture of a larger fraction of flood flows, is hydrologically feasible. In most years, the additional reservoir space evacuated is refilled by surplus surface flows that otherwise would have been lost as flood control releases. However, in some years, reservoir storage does not recover to levels that would have occurred without the additional releases, resulting in a reservoir storage deficit compared to baseline conditions.

2. To satisfy CVP and SWP supply obligations at current levels and to comply with current environmental regulations, especially those pertaining to water temperature, it is necessary to have a method for "paying back" any reservoir deficits resulting from the additional releases. The scale of the re-operation that is feasible without risk to water supply and project operations is limited by the capacity to pay back the reservoir because the maximum reservoir deficit cannot be larger than the ability to pay it back in a single year, when necessary.

3. At the two payback scales investigated (see Section 5), simulations indicate that between 27 thousand acre-feet (TAF) and 69 TAF of additional water supplies could be generated on an average annual basis from Shasta re-operation, while Oroville re-operation could yield between 17 TAF to 43 TAF on an average annual basis. However, these estimates do not take into account the minimum mandatory reservoir releases for temperature control or forecast-based reservoir operations as described below.)

4. Four strategies for reservoir payback have been identified as warranting consideration, three of which were analyzed in this phase of the project. The three payback mechanisms analyzed in this phase are:
    a. Drawing on project surplus water that would be banked through intentional recharge of groundwater at sites within the Sacramento Valley;
    b. Pumping groundwater within Glenn Colusa Irrigation District (GCID), a CVP settlement contractor, to pay back Shasta Reservoir and within Western Canal Water District (WCWD) and Richvale Irrigation District (RID), both served through the SWP collectively referred to as the "Butte Basin", to pay back Oroville Reservoir; and
    c. Reducing surface water demands through voluntary, temporary, and compensated idling of crop lands by willing growers in these participating districts[8].

5. Payback through groundwater banking in the Sacramento Valley proved to be infeasible because, under existing levels of groundwater use, the seasonally dewatered aquifer space tends to recharge annually during the following precipitation season. Cones of depression from groundwater pumping typically do not persist over the multiple years necessary for an efficient, actively recharged, banking operation. Therefore, additional recharge for water banking tends to

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[8] Another strategy for demand reduction is foregoing flooding rice lands at the end of the growing season for rice straw decomposition. The potential to substitute other means of disposing of the straw, such as removal to delta islands to rebuild their elevation, has not been analyzed because this option has the disadvantage of eliminating valuable waterfowl refugia during the late fall and winter seasons.

cause rejection of recharge from other sources or increased aquifer discharge, with little net gain in groundwater storage. Consequently, this payback option was not further pursued.

6. Payback through groundwater pumping within the participating water districts was found to be technically feasible with impacts on other existing groundwater users small enough to be mitigated and compensated. Impacts to the yields and operability of agricultural wells would be negligible, while up to approximately 3 percent of the large number (more than 9,000) of existing domestic wells would become inoperable and would therefore needed to be deepened or replaced. The pumping lift for all wells would increase resulting in increased pumping costs.

7. The investigation also addressed the feasibility of repaying the reservoirs through reducing water demands in the participating districts instead of pumping groundwater. This would have the advantage of avoiding entirely impacts on other groundwater users. This could be accomplished through a program of voluntary crop idling by growers in these districts pursuant to a water buy-back arrangement. This payback strategy proved to be inefficient because the decision to call on crop idling for payback must be made before the planting season begins, when the extent of reservoir refill is still highly uncertain. Particularly because end-of-season reservoir storage forecasts are made conservatively, there is a significant probability that the water made available through crop idling is either not needed or is spilled from the reservoir. Consequently this payback option does not perform as well as groundwater pumping from a cost-effectiveness perspective.[9]

8. The fourth payback mechanism, identified but not evaluated in this phase, involves drawing on project water banked in dewatered aquifers south of the delta. This option becomes much more viable if existing pumping constraints at the Banks and Jones plants in the south delta are alleviated by an isolated diversion and conveyance facility around or under the delta to the state and federal canals, such as is being considered in the Bay Delta Conservation Plan (BDCP). This option will be evaluated in the next phase by which time BDCP options presumably will have been clarified. It is notable that this option would allow the surplus water to be stored and used at times and places of greatest economic value, compared to the other strategies that were evaluated. It is also notable that this option would not entail increasing the volume of water that is exported from the Sacramento Valley currently, but would convert some portion of delta outflow during the flood season to water supply south of the delta.

9. All of the payback mechanisms investigated would be constrained during periods when reservoir releases governed by water quality objectives (mainly temperature) exceed the releases needed to serve downstream demands. Under these conditions, regardless of how it is generated, payback water cannot be held in upstream storage because reservoir releases cannot be reduced and still meet water quality objectives. Minimum releases at Keswick (on the Sacramento River) are prescribed by current water quality regulations imposed by the biological opinions of the National Marine Fisheries Service at the federal level and by the State Water Resources Control Board at the state level to prevent lethal temperature occurrence in the

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[9] Another strategy for implementing temporary crop idling was identified but not evaluated as part of the investigation. Rather than invoke crop idling prior to planting, the idea would be to trigger idling during the crop season when the determination of the need for and effectiveness of payback could be forecast with much greater reliability. Certain crops, such as alfalfa, are adapted to intermittent irrigation, although production losses more or less proportional to water shortages are expected.

Sacramento River for spring and winter run salmon. Operational protocols to maintain viable temperatures for the Feather River below the Thermalito re-regulation dam are also prescribed in the proposed settlement agreement for the Oroville relicensing by the Federal Energy Regulatory Commission (FERC). The extent to which these may also constrain the payback potential for Oroville should be analyzed further.. Like the other payback options, the extent to which the reservoir carryover storage can be reduced through additional releases for the project purposes (environmental flows and water supply) is limited by the ability to make up any storage deficits that result from insufficient reservoir inflow in subsequent precipitation seasons. Substituting groundwater pumping for surface water deliveries is a means to do that. But in the case of Shasta reservoir (and probably also Oroville reservoir under the FERC relicensing agreement), such substitution will only work to the extent that a commensurate amount of water can be retained in the reservoir. The requirement to release prescribed amounts of water at Keswick dam for temperature control means that in many years, groundwater pumping cannot completely replace reservoir water.

10. Shasta and Oroville Reservoirs are operated at present in a conservative manner that minimizes the risks of temperature stresses for salmonids in the downstream rivers. These conservative operations dramatically reduce potential improvements in environmental flows made possible by project conjunctive operations. Three of the project’s four environmental flow improvements are designed to benefit salmon through increased spring pulses for out-migration, floodplain inundation for rearing and food, and geomorphic flows to improve spawning conditions. Yet the more aggressive reservoir operations to generate these environmental flows unavoidably increase the risks to the cold water pool to some extent. It is apparent that there is a tradeoff between temperature risk reduction and environmental flow benefits. Whether the loss of suitable habitat in some reaches of the rivers due to adverse temperatures, if any, is more than offset by the improvements in habitat for salmon resulting from meeting the other environmental flow improvements more frequently will also be investigated in the next phase of this project. It is also possible that fish passage to access the cold water resources above the dams, such has been recommended by NMFS as a salmon recovery measure, would also alleviate the volume and timing of cold water releases needed for temperature control below the dams. This will also be investigated in the next phase. These subsequent investigations will illuminate whether the optimal strategy can result in less constraining minimum releases at Keswick and larger and more frequent yields of water for environmental flows and water supply.

11. Simulations of conjunctive operations with the effects of minimum reservoir releases for temperature control (in combination with forecast-based simulation techniques) revealed that project benefits are dramatically reduced, by approximately one-half to two-thirds of the levels discussed above in #3. At this scale, the economic benefits are also small in light of the costs of the projects, including primarily the energy cost for pumping payback groundwater and the costs of mitigating the effects of this pumping on other groundwater users.

12. The economic benefits of the project in the near term with this (groundwater pumping) payback mechanism include the market value of the additional water within the Sacramento Valley, estimated to be $50 per AF.

2. Introduction

2.1.Purpose

In 2006, the Glenn Colusa Irrigation District (GCID) and the Natural Heritage Institute (NHI) jointly embarked on this investigation to explore how the largest water storage reservoir in the Federal Central Valley Project (CVP), Shasta, and the only such reservoir in the State Water Project (SWP), Oroville, could be re-operated in conjunction with northern Sacramento Valley groundwater aquifers to increase water supplies for both environmental and economic uses. The investigation was enabled by a combination of state and federal grant funding, including Proposition 50 funding administered by the Department of Water Resources (DWR) and federal funds administered by the Bureau of Reclamation's (Reclamation) Mid-Pacific Region.

The potential of conjunctive water management in the Sacramento Valley has long been perceived as offering significant potential to produce additional water supplies due to the presence of large surface reservoirs and extensive, although not well understood, groundwater aquifers. Conceptual level investigations, including one completed by NHI in 1999, have generally confirmed this potential but have not fully taken into account the myriad factors governing reservoir operations, including the existing water supply obligations of the reservoirs, flood control functions and environmental regulations. The purpose of this investigation was to further investigate Sacramento Valley conjunctive management opportunities taking into consideration these constraints. Additionally, there has been little definitive investigation of the effects that aquifer recharge and additional pumping implicit to conjunctive management might have on groundwater conditions in the Sacramento Valley. This was also an objective of this investigation.

2.2.Evolution of Project Perspective and Scope

At its inception, the investigation focused on the Sacramento Valley's deep aquifers, particularly the Lower Tuscan Formation, which underlies much of the northern portion of the Sacramento Valley. However, as the investigation progressed the study team recognized that such a narrow focus was both overly constraining on the scope of the study and somewhat misleading because it implied that any effects on the aquifer system due to additional recharge or pumping could somehow be confined to a particular portion of the groundwater system. Ultimately the project evaluated the effects of exercising both the northern Sacramento Valley's deep aquifer system, which is presently relatively undeveloped, and the shallower, regional aquifer, which is more heavily pumped for both domestic and agricultural needs.

The investigation began with the expectation that surplus water generated through the re-operation of these reservoirs could be banked in the groundwater aquifers in the Sacramento Valley, like other conjunctive use programs in the San Joaquin Valley of California, with water put into groundwater storage in wet years and extracted in dry years. However, initial assessment and site screening revealed that conditions in the Sacramento Valley are not conducive to this mode of conjunctive management, primarily because groundwater aquifers, although extensively developed and pumped in many areas, mostly for agricultural irrigation, generally recover fully during the precipitation season. What emerged was a conjunctive management approach based on reservoir re-operation backstopped by several options for reducing the draw on reservoir storage when refill is insufficient.

The scope of the investigation included technical, economic, institutional and outreach components. Technical work concentrated on developing coordinated groundwater and surface water models for formulating and evaluating alternative conjunctive management strategies and project configurations. Model development consumed more time and a larger percentage of the project's resources than initially intended, which required reallocation of resources from the economic and institutional analyses. Robust outreach was conducted throughout the course of the effort at many different levels and in different forms.

The investigation was originally scoped to evaluate conjunctive water management opportunities within the Sacramento Valley. However, as the investigation proceeded, it became clear that there may be opportunities to enhance the cost-effectiveness of conjunctive operations through integration with Bay-Delta (Delta) export operations, depending to some degree on the outcomes of current efforts to address Delta issues and governance. Inasmuch as these outcomes are still highly uncertain, and to maintain consistency with the project's original scope, Delta export operations were not investigated but are discussed in the context of possible further investigation. It should be noted that, at a conceptual level, it appears that integration of Sacramento Valley conjunctive management with Delta export operations could provide in-Valley benefits with lower risk compared to the in-Valley configurations evaluated.

The other significant changes that occurred while the investigation was underway were the issuance of the 2008 Biological Opinion on delta smelt (smelt BO) and the 2009 Biological Opinion on Chinook salmon (salmon BO). The project baseline was adjusted during the course of investigation in response to requirements stemming from these changes.

2.3.Report Contents

Following this Introduction, the agencies that sponsored, participated in and funded the investigation are described and the public outreach process is summarized (Section 3). The analytic approach to the investigation is presented in Section 4. The discussion focuses on the core conjunctive operations concept of reservoir re-operation backed by groundwater pumping for reservoir "payback". Additionally, specific reservoir payback mechanisms are described and the objectives, principles and constraints that formed the analytical framework are presented.

The initial project scenarios are presented in Section 5, including descriptions of the scenarios, development of the analytic tools (models) used to formulate and evaluate potential project operations and summaries of how the scenarios performed in physical and economic terms. Section 5 concludes with a discussion of interim findings that shaped further analysis and refinement of project scenarios.

Section 6 describes the phase of the project involving collaboration with the operators of the Central Valley Project (CVP) and State Water Project (SWP). During this phase, in response to operators' suggestions, certain modifications were made to the analytic tools to incorporate constraints that presently govern CVP and SWP operations, particularly reservoir operations for cold water management and additional project objectives were assessed. These factors are described along with the conclusions drawn from the refined and extended analysis.

Finally, in Section 7, ideas and suggestions to guide further investigation of Sacramento Valley conjunctive water management are offered. Among the recommendations are suggestions to investigate integration with Delta export operations.

2.4.Acknowledgements

NHI and GCID are grateful for the opportunity to sponsor this investigation and wish to acknowledge DWR and Reclamation for awarding the enabling grant funds. Additionally, DWR provided groundwater well information and other data without which development of analytic tools and evaluation of impacts of additional groundwater pumping would not have been possible.

In particular, the sponsors wish to thank the individual DWR and Reclamation staff members who operate the CVP and SWP and gave freely of their time during the collaborative phase to enhance the pertinence of the investigation.

Finally, the sponsors are grateful to the many members of the public and representatives of public interest groups who participated in the project's public meetings. The comments received during these meetings were heard and carefully considered.

3. Project Sponsors, Participants and Donors

3.1.Sponsors

3.1.1. Glenn Colusa Irrigation District

The Glenn-Colusa Irrigation District (GCID) appropriative water rights begin on the Sacramento River with an 1883 filing posted on a tree by Will S. Green, surveyor, newspaperman, public official, and pioneer irrigator. His first claim was for 500,000 miner's inches under 4 inches of pressure and was one of the earliest and largest water rights on the Sacramento River.

GCID was organized in 1920, after several private companies failed financially, and a group of landowners reorganized and refinanced the irrigation district, retaining claim to Green's historic water right. The disastrous rice crop failure of 1920–21 nearly destroyed the district at its inception, and the "great depression" took a further toll, making it necessary for the district to refinance in the 1930s. Additionally, the United States purchased lands within GCID during this period which would later become three federal refuges totaling approximately 20,000 acres.

Today, after surviving many challenges, GCID is the largest district in the Sacramento Valley. Located approximately eighty miles north of Sacramento, California, the district boundaries cover approximately 175,000 acres; of which 153,000 acres are deeded property and 138,800 are irrigable. There are 1,076 landowners in the District and an additional 300 tenant water users. There are an additional 5,000 acres of private habitat land, and winter water supplied by GCID to thousands of acres of rice land provides valuable habitat for migrating waterfowl during the winter months.

GCID's main pump station, its only diversion from the Sacramento River, is located near Hamilton City. The District's 65-mile long Main Canal conveys water into a complex system of nearly 1,000 miles of canals, laterals and drains, much of it constructed in the early 1900s. The District headquarters are located in Willows, the county seat of Glenn County, approximately 90 miles north of Sacramento on Interstate 5.

A five-member board of directors, who represent five subdivisions within the District, governs the District. The annual budget is $15 million. GCID's mission is to provide reliable, affordable water supplies to its landowners and water users, while ensuring the environmental and economic viability of the region.

From its first diversions until 1964, GCID relied upon its historic water rights and adequate water supply from the Sacramento River hydrologic system which receives rainfall and snowmelt from a 27,246 square mile watershed with average runoff of 22,389,000 acre-feet, providing nearly one-third of the state's total natural runoff. In 1964, after nearly two decades of negotiations with the United States, GCID along with other Sacramento River water rights diverters entered into "Settlement Water Contracts" with the Bureau of Reclamation (Bureau). These Settlement Contracts were necessary at that time to allow the Bureau to construct, operate, and divert water for the newly constructed Central Valley Project. The contract provided GCID with water supply for the months of April through October for 720,000 acre-feet of base supply, and 105,000 acre-feet of Central Valley Project water that is purchased during the months of July and August. During a designated critical year when natural inflow to Shasta Reservoir is less than 3.2 million acre-feet, GCID's total supply is reduced by 25 percent, to a total of 618,000 acre-feet.

Additionally, the District has rights under a State Water Resources Control Board (SWRCB) permit to "winter water" from November 1 through March 31 at a 1,200 cubic feet per second (cfs) diversion rate. This water supply is used for rice straw decomposition and waterfowl habitat. The permit provides 150,000 acre-feet for rice straw decomposition and 32,900 acre-feet for crop consumption. Groundwater can be used to supplement GCID's supplies, with 5,000 acre-feet available from District wells, and approximately 45,000 acre-feet from privately owned landowner wells.

3.1.2. Natural Heritage Institute

Natural Heritage Institute (NHI) is a non-governmental, non-profit organization founded in 1989 to restore and protect the natural functions that support water-dependent ecosystems and the services they provide to sustain and enrich human life. Its founders foresaw the need for a toolkit for the next era of environmental problem-solving: where the technical challenges are more complex, the solutions more elusive, the economics more central, the ramifications more global, and the conventional pathways less efficacious. NHI is motivated by the realization that, when the earth's limited stock of natural resources is squandered, the legacy bequeathed to future generations is impoverished, sometimes for all time. The only hope for this beleaguered planet is to do more with less and to restore the damage of the past. Increasingly, the environmental challenge is to move from strategies that freeze the status quo to those that ensure that the economic use of natural resources also yields net environmental gains.

Previous work by NHI has shown that re-operating existing Central Valley reservoirs in conjunction with groundwater banks could generate surplus water to restore more natural flow patterns in the eleven regulated tributaries of the Central Valley – comprising by far the largest ecosystem restoration program ever undertaken in this geography – while also satisfying growing demand from agricultural and urban users. Because it utilizes existing infrastructure, conjunctive management is faster and less costly to implement than other water supply augmentation strategies. Indeed, it could generate more new water supply than any other current alternative, and, uniquely, do so without any governmental subsidies.

The system-wide analysis has now progressed through the "proof of concept" stage, and NHI is applying the results in regional demonstration projects. The first regional component is being pursued in the Sacramento Valley through this investigation in collaboration with the Glenn Colusa Irrigation District. This work in the Central Valley of California serves as a model for conjunctive water management in watersheds worldwide through NHI's Global Dam Re-optimization Initiative, which is funded by major foundation, national governments and intergovernmental organizations.

3.2. Participating Water Suppliers

Western Canal Water District (WCWD) and neighboring Richvale Water District (RID) elected to participate in this study in a passive manner by expressing their interest in potential willingness to support a conjunctive management project, subject to the findings of the investigation. WCWD and RID are two of four districts collectively referred to as the Joint Water Districts, the others being Biggs West Gridley Water District (BWGWD) and Butte Water District (BWD). Each year, on average, the Joint Water Districts import about 610 TAF of Feather River water into Butte Basin for irrigation purposes. The unconsumed portion of the imported flows serve in part to recharge underlying aquifers and to sustain flows that serve as supply sources for downstream water users.

3.2.1. Western Canal Water District

Western Canal Water District was formed by an election of District landowners on December 18, 1984, which elected five Directors and authorized the purchase of the District from Pacific Gas and Electric Company. PG&E had obtained the District from their predecessor, The Great Western Power Company, who had developed the hydroelectric power facilities on the Feather River early in the 1900s. The acquisition included pre-1914 water rights on the Feather River for use by the District. These consist of 150,000 acre feet of natural flow of the river and 145,000 acre feet of water stored in the North Fork Feather River Project. The District also has adjudicated rights to a small amount of Butte Creek water.

WCWD is comprised of a gross area of 65,000 acres with irrigable acreage of about 58,500 acres. The primary crop is rice with a small amount of pasture and orchard crops. The District has ten employees and an operations budget of about $1.3M. Two-thirds of the District lies in Butte County, and the rest in Glenn County.

In 1998, the District completed the WCWD Fish Passage Improvement Project, which allowed for removal of four dams on Butte Creek. Butte Creek is one of three remaining tributaries to the Sacramento River that sustain a Spring-Run Chinook salmon population. This award winning project was funded by WCWD, the Department of Interior, and CALFED at a cost of $9.1M.

WCWD supports conjunctive use of groundwater and surface water in order to most efficiently and effectively use the resource for maximum benefit to the local area as well as the entire state, and has participated in several drought years to assist the State Water Bank by facilitating groundwater substitution exchanges. WCWD has developed a Groundwater Management Plan with Rules and Regulations, which provide for conjunctive use in a responsible and safe manner. The District strives to protect their water rights while working in a in a cooperative manner with all users of the water resources, locally and on a statewide basis.

3.2.2. Richvale Irrigation District

Richvale Irrigation District (RID) was formed on July 7, 1930 by purchasing a portion of the Sutter Butte Canal Company. Governance is provided by a three member Board of Directors that appoints a treasurer and employs a District Secretary/General Manager. The director terms are four years and rotate on odd years.

RID holds pre-1914 water rights to the Feather River in conjunction with three other districts (Western Canal Water District, Biggs West Gridley and Butte Water District) that make up the Joint Water Districts. RID consists of approximately 34,000 irrigable acres with rice being the primary crop. RID’s service area includes the Upper Butte Basin Wildlife Area.

RID has a water service contract with DWR for an annual allocation of 149,850 acre feet. All of the district deliveries are made through intake structures utilizing a screw gate or flashboard weir type structures. All water is distributed through earthen canals by gravity flow.

3.3.Funding Agencies

3.3.1. Department of Water Resources

The mission of the California Department of Water Resources (DWR) is to manage the water resources of California in cooperation with other agencies, to benefit the State’s people, and to protect, restore, and enhance the natural and human environments. To this end and in support of the legislative objectives of DWR, development of a System Re-operation Program (SRP) that will identify viable re-operation strategies of California's statewide water system, has been an ongoing process comprised of a diverse set of local, state, and federal agencies. The Glenn Colusa Irrigation District (GCID) is one such local agency that has teamed with DWR to explore the feasibility of an Integrated Regional Water Management Program (IRWMP) in the Northern Sacramento Valley region as a potential integral part of the SRP. Funding for the GCID IRWMP is made possible through DWR's Water Supply Reliability Program (a portion of the voter-approved Proposition 50 water bond measure) and primarily works toward achieving three of DWR eight Strategic Planning Goals as follows:

Goal 2	Plan, design, construct, operate, and maintain the State Water Project to achieve maximum flexibility, safety, and reliability.
Goal 3	Protect and improve the water resources and dependent ecosystems of statewide significance, including the Sacramento-San Joaquin Bay-Delta Estuary.
Goal 6	Support local planning and integrated regional water management through technical and financial assistance.

While a Coordinated Operating Agreement that was initiated in the 1970's and finalized in 1986 has instilled a significant degree of integration between operation of the State's two largest water management systems, the State Water Project (SWP) and the federal government's Central Valley Project (CVP) that were otherwise designed as standalone systems, the GCID IRWMP seeks to further explore opportunities to re-operate portions of California's statewide water system to yield increased water resources related benefits. In addition, recent action by the State Legislature in Senate Bill X2 1 (SB X2 1) (Perata, 2008 – Water Code Section 83002.5), mandates and allocates resources for "planning and feasibility studies to identify potential options for the re-operation of the state's flood protection and water supply systems that optimize the use of existing facilities and groundwater storage capacity. Specifically, SB X2 1 stipulated that the studies shall incorporate appropriate climate change strategies and be designed to determine the potential to achieve, among other things, the following objectives:

- Integration of flood protection and water supply systems to increase water supply reliability and flood protection, improve water quality, and provide for ecosystem protection and restoration.
- Re-operation of existing reservoirs, flood facilities, and other water facilities in conjunction with groundwater storage to improve water supply reliability, flood hazard reduction, and ecosystem protection and to reduce groundwater overdraft.
- Promotion of more effective groundwater management and protection and greater integration of groundwater and surface water resource uses.
- Improvement of existing water conveyance systems to increase water supply reliability, improve water quality, expand flood protection, and protect and restore ecosystems.

3.3.2. Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. Through leadership, use of technical expertise, efficient operations, responsive customer service and the creativity of people, Reclamation seeks to protect local economies and preserve natural resources and ecosystems through the effective use of water.

The Mid-Pacific Region (MP Region) of the Bureau of Reclamation was created by the Secretary of the Interior in 1942. MP Region comprises numerous dams, reservoirs and conveyances that provide water for urban, industrial, agricultural, and fish and wildlife/environmental uses; generate hydro-electric power; and provide for flood protection, river navigation, and recreation. The Region includes lands from Klamath Falls, Oregon, south to Bakersfield, California, and most of northwestern Nevada. The MP Region is one of five Regions that carry on day-to-day planning, management, and operational activities for the Bureau of Reclamation.

Created by the Secretary of the Interior in 1942, the MP Region is headquartered in Sacramento, California and has Area Offices located at Shasta Lake, Folsom, and Fresno, California; Carson City, Nevada; and Klamath Falls, Oregon. Supporting offices include the Central Valley Operations Office in Sacramento and the Mid-Pacific Construction Office in Willows, CA.

The Mid-Pacific Region is best known for the massive Central Valley Project (CVP) built to tame the flood waters and irrigate the semi-arid acreage of California's vast Central Valley, the CVP grew over the last 50 years to become one of the largest water storage and transport systems in the world. The CVP is a system of 20 reservoirs and more than 500 miles of major canals and aqueducts that encompasses 35 counties. The CVP has a combined storage capacity of more than 11 million acre-feet of water, manages approximately 9 million acre-feet of water, and delivers more than 7 million acre-feet in a year, more than any other single California agency in a normal year. There are 11 hydroelectric power plants providing an average of 5.5 billion kilowatt hours of electricity to supply around 1.5 million people with power throughout the Mid-Pacific Region.

3.4.Public Outreach

Public outreach was conducted in a variety of forms to guide development of the project and to inform interested parties. The various meetings held to effect outreach, as well as achieve technical coordination among the project team, are listed in Table 3-1 and discussed in the following subsections.

3.4.1. Public Outreach

A total of seven public outreach meetings were conducted during the course of the project to both inform the public and to solicit feedback to guide the project’s direction. Initial public outreach concentrated on Sacramento Valley counties and consisted of two formal meetings complemented by informal one-on-one discussions with key county staff and elected officials. These meetings were very useful in framing local and regional sensitivities, and provided good background for scoping and directing the project.

Later, the team engaged the public through publicly noticed meetings, which generally drew sizeable, interested crowds and generated useful dialogue and feedback. Three public meetings were held in the latter half of 2008 and two more in late 2010 for this purpose. All meetings were held in the Chico vicinity. Materials for the two 2010 meetings (October 21 and December 8) are included in Appendix A.

3.4.2. Executive Briefings

Three executive briefings were provided by the team, two with DWR management and staff and one with Reclamation management and staff. These briefings generally consisted of high-level overviews of project status, with emphasis on linkage and coordination with related agency initiatives.

TABLE 3-1
Chronological List of Outreach and Technical Team Meetings
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Event #	Date	Location	Meeting Type	Participants	Purpose/Notes
1	11/16/2006	GCID	Public Oureach	GCID, NHI, Sac Valley county staff	General information; gauge interest; gather feedback
2	12/19/2006	GCID	Public Oureach	GCID, NHI, Sac Valley county staff	General information; gauge interest; gather feedback
3	6/19/2007	MBK Engineers/Sacramento	Technical	GCID, NHI, technical team members	Project site selection, model development, environmental flows
4	7/30/2007	MBK Engineers/Sacramento	Technical	GCID, NHI, technical team members	Project site selection, model development, environmental flows
5	9/21/2007	MBK Engineers/Sacramento	Project Coordination	GCID-NHI	Comprehensive review of technical work; strategic issues
6	9/21/2007	MBK Engineers/Sacramento	Technical	GCID, NHI, technical team members, DWR staff	Project site selection, model development, environmental flows; Delta issues
7	10/23/2007	MBK Engineers/Sacramento	Technical	GCID, NHI, technical team members, DWR staff	Model develop and interaction; environmental flows
8	2/25/2008	MBK Engineers/Sacramento	Technical	GCID, NHI, technical team members, DWR staff	Model develop and interaction; environmental flows
9	5/23/2008	MBK Engineers/Sacramento	Technical	GCID, NHI, technical team members, DWR staff	Model develop and interaction
10	5/29/2008	MBK Engineers/Sacramento	Technical	Modeling subteam (selected technical team members)	Model development and calibration
11	6/18/2008	MBK Engineers/Sacramento	Technical	Modeling subteam (selected technical team members)	Model update and demonstration
12	7/8/2008	MBK Engineers/Sacramento	Technical	Modeling subteam (selected technical team members)	Model update and demonstration
13	8/4/2008	Chico City Hall	Public Oureach	GCID, NHI, Chico area interested/concerned parties	Respond to particular concerns and quesitons raised by participants
14	9/5/2008	DWR/Sacramento	Executive Briefing	NHI, Tracie Billington/DWR	General information/update
15	9/16/2008	GCID Pump Station/Hamilton City	Public Oureach	GCID, NHI, Sacramento Valley public	Update public and receive comment on recent project activities
16	12/8/2008	Durham	Public Oureach	GCID, NHI, Sacramento Valley public	Update public and receive comment on recent project activities
17	1/6/2009	CirclePoint/Sacramento	Planning Meeting	GCID, NHI, program manager	Comprehensive review of technical work and public outreach
18	5/1/2009	MBK Engineers	Technical	Tech Team	Develop methodology for assessing groundwater impacts
19	8/11/2009	USBR/Sacramento	Executive Briefing	NHI, GCID, Don Glaser/USBR, USBR staff	General information/update
20	1/6/2010	Davids Engineering/Davis	Technical	GCID, NHI, technical team members	Project economics
21	4/8/2010	CVO/Sacramento	Workshop	CVP and SWP operators	Collaborative Workshop #1
22	6/11/2010	San Francisco	Executive Briefing	NHI Annual Board Meeting	General information
23	7/9/2010	CVO/Sacramento	Workshop	CVP and SWP operators	Collaborative Workshop #2
24	9/8/2010	MBK Engineers/Sacramento	Workshop	CVP and SWP operators	Collaborative Workshop #3
25	10/21/2010	Chico	Public Oureach	GCID, NHI, Sacramento Valley public	Update public and receive comment on recent project activities
26	12/8/2010	Masonic Lodge/Chico	Public Workshop/Oureach	GCID, NHI, Sacramento Valley public	Update public and receive comment on recent project activities
27	3/17/2011	DWR/Sacramento	Executive Briefing	Ajay, Goyal and DWR	Coordination with other DWR initiatives

3.4.3. Workshops

Three of the four workshops conducted for the project were held specifically to engage the CVP and SWP operators. These workshops were used to present the results of technical analyses and to frame and discuss the various assumptions being made by the team regarding existing operation of the CVP and SWP and implications and opportunities associated with conjunctive operations. These workshops were invaluable in refining the project's analytic tools and operations simulations. (Also see section 6.)

The fourth project workshop was designed to engage the Chico area public specifically to walk through the unique conjunctive operation strategy identified for the project (which emphasizes reservoir re-operation backed by limited groundwater pumping).

3.4.4. Technical and Other Team Meetings

During the initial technical formulation of the project from roughly mid-2007 through mid-2008, a series of rigorous meetings were held among the technical team, but also including agency staff. It was during these meetings that the core conjunctive operations concept was developed, project areas screened and models developed and tested. In some cases, adjunct meetings of the project sponsors were conducted before or after the technical team sessions to discuss project strategic issues.

Other project coordination and planning meetings were held occasionally, as needed, to ensure adequate coordination among team members and with the funding agencies.

4. Analytic Approach

4.1.Overview

Development of project scenarios evolved over the period from 2007 to 2011 including efforts to develop appropriate analytic tools (or models) and to evaluate model outputs and project performance (Figure 4-1). Scenario development began by framing projects objectives and principles consistent with the original project proposals but also reflecting input received through initial public outreach. Once these guiding materials were developed, efforts branched onto two parallel, coordinated tracks, one to develop specific environmental flow targets for the Sacramento and Feather Rivers, and another to identify areas within the Sacramento Valley for more detailed investigation. Information compiled for project site screening also provided a basis for assessing different conjunctive operations modes at a conceptual level, leading to identification of the most promising conjunctive management approaches.

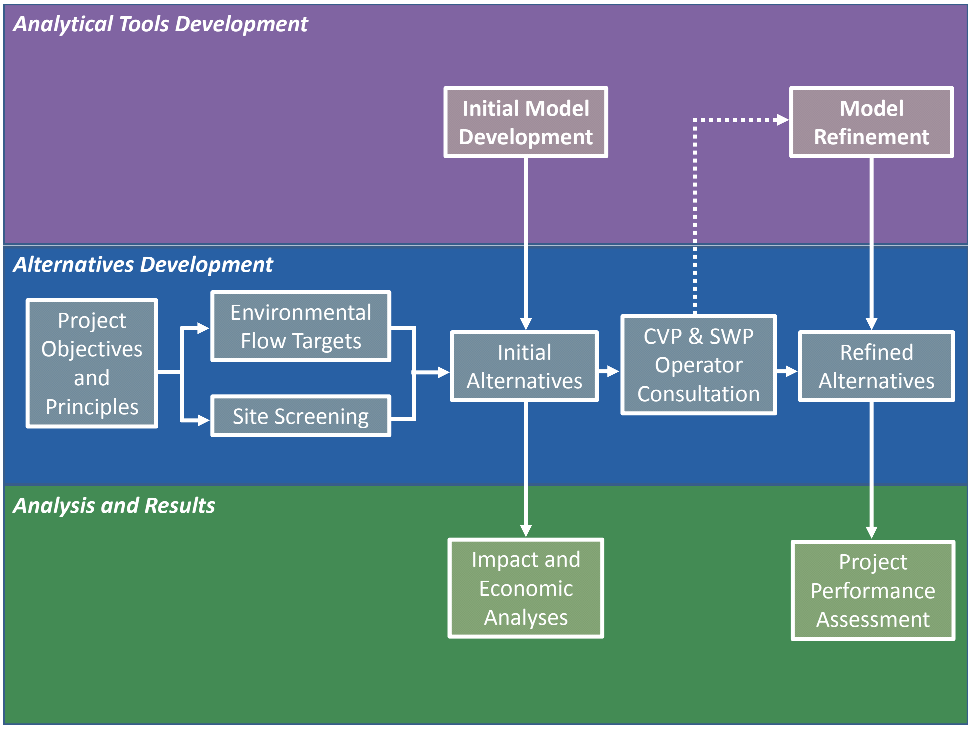

FIGURE 4-1
Project Analytical Components
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

With environmental flow targets established and a clear vision of the conjunctive operations strategy, work began on development of the scenarios themselves and supporting analytical tools. The initial project scenarios that resulted were analyzed in detail, providing a basis for additional public outreach and focused consultations with the operators of the Central Valley Project and State Water Project. The consultation with project operators was particularly instructive, leading to important refinement of the project scenarios and identification of additional project objectives to be tested, along with some as refinement of the models themselves.

The project's core conjunctive operations concept, site screening process and develop of environmental flow targets are discussed in detail in this section (Section 4). Initial model development and scenario development and evaluation are discussed in Section 5, with Section 6 covering model and scenarios refinement and assessment of project performance. The relationship between the analytic components and report structure are presented below in Figure 4-2.

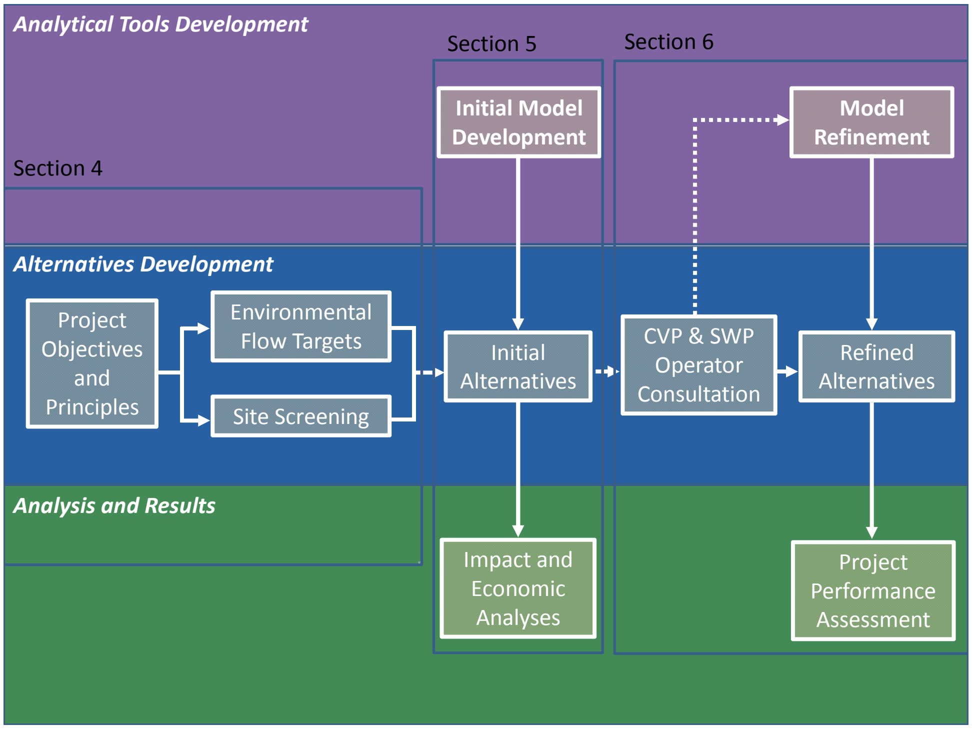

FIGURE 4-2
Relationship between Analytical and Report Organization
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

4.2.The Core Reservoir Re-operation and Payback Concept

The central thesis of this investigation is that most major reservoirs that are operated today for a limited set of water supply and flood control objectives could be re-operated to achieve newly defined ecological restoration benefits while also improving water supply reliability, reducing flood risks, and buffering the effects of climate change. The objective of the project was to explore the potential to optimize operations for all of these benefits without compromising any of them. This opportunity was recognized by the authors of CALFED's Strategic Plan for Ecosystem Restoration:

> "There is underutilized potential to modify reservoir operations rules to create more dynamic, natural high-flow regimes in regulated rivers without seriously impinging the water storage purposes for which the reservoir was constructed. Water release operating rules could be changed to ensure greater variability of flow, provide adequate spring flows for riparian vegetation establishment, simulate effects of natural floods in scouring riverbeds and creating point bars, and increase the frequency and duration of overflow onto adjacent floodplains[10]."

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[10] CALFED Bay-Delta Program, Ecosystem Restoration Program Plan, Strategic Plan for Ecosystem Restoration, Final programmatic EIS/EIR technical Appendix, July 2000.

Reservoirs that have dual water supply and flood control functions, like the CVP and SWP reservoirs, are typically operated under conservative rules designed to maximize water supply while avoiding flood risks. This results in relative high carryover storage levels but frequent “spills” of water during the refill period to create sufficient flood reservation capacity as necessary to prevent flood damage to the development that has occurred in the downstream floodplain. These spills represent the component of the runoff hydrograph that is not controlled and therefore not appropriated for beneficial use under California water law. To capture and manage this water would require creating additional storage capacity. One way to do that without enlarging the reservoir, or constructing additional ones, is to lower the water storage levels going into the refill period, thereby creating more reservoir capacity to capture high flows. Storage levels can be lowered by delivering additional water from the conservation pool to meet new water supply objectives, including enhancing flows for environmental benefits and augmenting water supplies for consumptive uses such as agriculture.

However, making additional reservoir releases before the ensuing refill period incurs a larger risk of water supply shortages in the event that the quantity of runoff during the refill season, which is always uncertain, is not sufficient to recover the reservoir storage to the level that would have occurred if the additional releases had not been made. Failure for the reservoir to refill would impinge on the reservoir’s function, manifest as water supply shortages, inadequate cold water reserves or reduced carryover storage, or some combination of these factors, unless the reservoir deficit can be made up from other sources.

The concept of re-operation described above was investigated in relation to Sacramento Valley reservoirs, including three options for filling any reservoir storage deficits caused by re-operation. The three options, referred to as reservoir “payback”, are listed below. It should be noted that payback does not involve sending water to the reservoir from other sources. Rather, the reservoir is “paid back” by not releasing water from it that otherwise could be called on, and meeting the water demands that would have been met with reservoir releases with other supplies, or by reducing water demands. The three payback options considered in this study are:

1. Payback from water generated by the project in previous years and stored (or “banked”) in aquifers in the Sacramento Valley;

2. Payback from groundwater pumped by cooperating water suppliers served by the CVP or SWP to substitute for water that would otherwise have had to be delivered from the reservoirs; and,

3. Payback from reduction in water demands on the reservoirs, achieved by temporary crop idling on a voluntary, compensated basis.

Each of these payback options is discussed in greater detail later in this section.

A fourth option that was not considered in this study is to repay reservoirs with water conveyed to and banked in aquifers south of the Delta in previous years. This option poses certain advantages to the Sacramento Valley by eliminating or substantially reducing the need to exercise Sacramento Valley aquifers for payback. However, this option is beyond the scope of this phase of investigation and would be overly speculative at this time given the uncertainty in the status and configuration of Delta conveyance and export options presently being evaluated under the Bay Delta Conservation Plan (BDCP).

4.3.Project Objectives, Design Principles and Constraints

The basic objective of reservoir re-operation is to generate additional water supplies (or “assets”) for discretionary uses. In this case, the investigation looked at dedicating additional water supplies generated through re-operation of Sacramento Valley reservoirs to two primary in-Valley purposes:

1. **Enhancing ecosystem functions in the Sacramento and Feather Rivers.** Healthy rivers are not just environmentally attractive, they also are central to ensuring reliable, sustainable water supplies. Water supply systems that work in concert with the environment are less likely to be encumbered by court orders, water rights hearings, and other restrictions that can have drastic effects on water supplies for farming and other economic uses.

2. **Improving local water supply reliability, particularly in times of scarcity**, to help fill water supply shortages that occur occasionally during hydrologically dry periods. The investigation used historical unmet agricultural water demands to represent the need for additional water supplies in the Valley; however, the additional water supplies could be allocated to other uses and locations.

While not an explicit component of the investigation, it should be noted that the additional water released for ecosystem enhancement becomes additional Delta inflow, which could be used for meeting Delta water quality objectives, for export from the Delta to meet water demands elsewhere in the state or some combination of the two. As discussed later in this report, to the extent that additional Delta exports could be generated while Sacramento Valley water supply reliability is increased and Delta water quality requirements are satisfied, the economic viability of reservoir re-operation and payback would be dramatically improved. Further investigation is needed to examine how these benefits could be optimized.

Design principles were established early on to guide development of project scenarios. The principles were derived in part from public input as well as from the sensibilities of the project sponsors and funding agencies, all aimed at identifying realistic, implementable water management improvements. The primary design principles are as follows:

1. Honor all existing CVP and SWP obligations and operational constraints: The CVP and SWP operate under a complex set of rules and conventions consistent with project water supply and flood control objectives and regulatory requirements, including temperature criteria, State Water Resources Control Board (SWRCB) Decision 1640 (D-1640), and the Central Valley Project Improvement Act (CVPIA). All of these existing objectives and constraints must be observed in any conjunctive management scenario so that water supply obligations to contractors are met to the same extent as under existing operations, and all applicable regulations are satisfied.

2. Achieve net environmental benefits, recognizing that there may be some tradeoffs among different environmental objectives and different times and locations: The Project would be operated to achieve or contribute to achieving certain environmental flow improvements in the mainstem Sacramento and Feather Rivers designed specifically to enhance ecologic functions important to the viability of protected species, particularly Chinook salmon. When groundwater pumping is needed for reservoir payback (under payback option #2, above), this could result in temporary reductions in base flows in the tributary streams that are also important to protected species. Such potential tradeoffs would be addressed through consultation with the listing

agencies as part of the NEPA/CEQA compliance by project sponsors. Additional tradeoffs between restoration of more natural river flow regimes and maintenance of cold water pools for river temperature control are also possible and are discussed later in this report.

3. Hold other groundwater users harmless: The participating water districts are legal users of groundwater, and, like all other groundwater users in the basin, enjoy a correlative and co-equal right to increase their groundwater extractions for use by the overlying landowners, subject to the mutual avoidance of harm. Notwithstanding the legality of the participating districts' groundwater withdrawals, the Project would adhere to a "good neighbor" principle and design its mitigation plan to the higher standard of assuring no appreciable, unmitigated harm to existing groundwater users.

4. Generate net economic benefits so that the program can be self-financing: The project must be able to generate revenues that more than offset the expenditures associated with project implementation, including construction, operation, maintenance and any mitigation costs. In the economic analysis conducted for the study, revenues were included only for water sales; no monetary value was attached to ecosystem restoration benefits, although these benefits may be quite appreciable.

Given the project objectives and design principles set forth above, certain constraints emerged during formulation and evaluation of project scenarios that limit the feasible scale of reservoir re-operation. These are listed below and are described at length later in this report.

- Capacity to produce water for reservoir payback. The capacity to produce water for reservoir payback governs the scale of reservoir re-operation, considering that the water debt owed to any reservoir cannot exceed the capacity to repay the reservoir payback in a single year, if necessary. However, particularly for reservoir payback based on additional groundwater pumping (option #2 above), the greater the payback capacity the greater the risk of impacting existing groundwater pumpers and critical streams.

- Minimum reservoir releases governed by temperature control criteria. There are conditions under which Lake Shasta reservoir releases are governed by temperature management in the Sacramento River between Keswick and Red Bluff, upstream of the locations were payback water would be generated. Under these conditions, the payback mechanism is rendered ineffective because reservoir releases cannot be reduced commensurate with the production of payback water. (The prospective temperature standards for the Feather River under the relicensing settlement for Oroville may also pose a constraint on re-operation of Lake Oroville for project purposes, but this has not yet been evaluated).

Within these limits, the investigation considered whether it is feasible through reservoir re-operation to increase the benefits that can be derived from a fixed hydrology and surface storage infrastructure.

4.4. Reservoir Payback Mechanisms

4.4.1. Groundwater Banking

Groundwater banking for reservoir payback involves making additional reservoir releases at certain times and storing the water in aquifers for recovery months or years later. Releases generally are made in above normal or wetter years with recovery occurring in relatively dry years. Surface water can be placed in storage by artificial recharge (surface spreading or injection wells) or by supplying it to water users who would otherwise pump groundwater (in-lieu recharge). Conditions required for groundwater banking include available storage space in an aquifer where water can be retained over periods of several years and a feasible means of recharge. Typically, in-lieu recharge is more cost-effective than artificial recharge; however, in-lieu recharge requires that there is baseline groundwater pumping that can be suspended at times when additional reservoir releases are being made. Thus, in areas where groundwater pumping is negligible or would not occur when reservoir releases would be made, in-lieu recharge is not feasible.

4.4.2. Groundwater Pumping

Groundwater pumping for reservoir payback without having first banked the water underground implies depleting groundwater storage. In order to be sustainable, groundwater storage depletion must be temporary with depletions eventually offset by additional recharge induced by the pumping. Additionally, practical restrictions need to be placed on the location, frequency, magnitude and duration of pumping to avoid or minimize any impacts to streams and existing groundwater users.

4.4.3. Temporary Crop Idling

Temporary crop idling involves not planting crops that would otherwise be grown and irrigated. Suspension of irrigation in this manner reduces demands on the reservoir being re-operated, allowing water to be held in storage that would otherwise be released. In order to attract farmers into voluntary participation in temporary crop idling programs, they must be compensated at a level that, at a minimum, provides a net benefit equivalent to production of the crop not planted. One of the main challenges to effective crop idling is the timing of decisionmaking by participating farmers relative to decisions that need to be made for project operations. Farmers typically are making crop decisions and purchasing production inputs in late winter into early spring meaning that offers to participate in crop idling must be presented in the same timeframe. However, at that time, the need for refill water cannot be forecast accurately while the commitments to idling and the associated payments are irrevocable. Thus, with crop idling, there is the possibility that actual reservoir inflow turns out to be greater than forecast, potentially rendering the water produced by crop idling unusable.

4.5. Project Site Screening

A systematic, qualitative assessment of conditions within the Sacramento Valley was conducted to identify particular areas where conjunctive operations appear promising. This process did not conclusively identify the very best or most feasible sites within the Valley, but did identify relatively attractive sites for conjunctive operations based on a comparative assessment using certain criteria.

The team examined fall groundwater elevation maps, water supplier boundaries and distribution system coverages, and water source maps. Initially it was assumed that conjunctive management operations would follow groundwater banking type operations wherein water is stored in aquifers during years of above normal water supply and extracted during years of below normal supply. These operations are typical in the San Joaquin Valley and other areas in which aquifers have been depleted and appreciable storage space exists. Following this initial assumption, the following two types of sites were identified:

- Areas in which existing groundwater levels may be lower than surrounding areas and overlying lands are supplied almost exclusively from groundwater. This type of site may provide the potential for groundwater banking in underlying aquifers.

- Areas in which minimal groundwater pumping exists because overlying areas are supplied almost exclusively from surface water. This type of site may provide a potential area for groundwater pumping.

The project and technical teams developed and initial list of project sites from a review of groundwater maps and their professional knowledge of the Sacramento Valley. Sites were named according to the overlying water district, though potential sites did not strictly conform to water district boundaries. Information considered in this analysis included the location, water source, existing surface water contracts, current infrastructure and additional infrastructure necessary for delivery of surface water and for extraction of groundwater, operational concepts, and information on existing groundwater conditions. Table 4-1 summarizes this information considered for the nine initial sites.

TABLE 4-1
Initial Project Sites and Parameters
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Location	Water Source	Site Type	Annual Surface Water Contract	Project to Integrate With	Currently Integrated?
Butte Basin	Surface	GW Pumping	~ 300 TAF/yr	SWP	Yes
Orland-Artois WD	Mixed	Both	53 TAF/yr	CVP	Yes
Rancho Capay WD	Ground	GW Banking	None	CVP	No
Corning Canal Area	Mixed	Both	33 TAF/yr	CVP	Yes
Yolo-Zamora WD	Ground	GW Banking	None	CVP	No
Glenn-Colusa ID	Surface	GW Pumping	825 TAF/yr	CVP	Yes
Stony Creek Fan area	Surface	GW Pumping	~ 100 TAF/yr	Orland	No
Colusa County WD	Mixed	Both	68 TAF/yr	CVP	Yes
Olive Percy Davis Ranch	Surface	GW Pumping	32 TAF/yr	CVP	Yes

The goal was to identify at least one site that is served by the CVP (Shasta), one by the SWP (Oroville), and one by the Orland Project. The CVP and SWP are the principal surface water systems in the Sacramento River basin and their operations are linked to the Sacramento and Feather Rivers, respectively, both of which are targeted for environmental restoration. The Orland Project, although not among the largest surface water systems in the Valley, is an area where conjunctive operations have been viewed as a possibility for many years.

The nine sites were evaluated qualitatively based on their potential to generate reservoir payback water, an estimate of the volume of water that may be developed, and relative (compared to the other sites) ease and cost of integrating the project with existing surface water systems.

The following additional criteria were used to identify prospective sites:

- Availability of reliable surface water supplies that could be substituted with groundwater to enable conjunctive operations

- The presence of highly productive, underlying groundwater aquifers that could be economically developed (or were already developed to some extent)

- The ability to locate and design production wells in a manner that would minimize effects on existing groundwater users and surface streams

Evaluation of existing groundwater conditions within the Sacramento Valley shaped the site screening and selection. In general, the evaluation revealed that while groundwater levels are drawn down during the irrigation season in many areas of the basin, levels recover during the precipitation season except during prolonged (multi-year) dry periods. Figures 4-1 through 4-15 of the Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report in Appendix B, which depict historic groundwater fluctuations in wells distributed throughout the valley, illustrate this point. Cones of depression generally do not persist over the multiple years necessary to make the dewatered aquifer space suitable for banking[11]. Any additional water recharge induces additional groundwater discharge to the streams. The conclusion from this analysis was that conjunctive operations based on a groundwater banking payback mechanism are not feasible in the Sacramento Valley at this time. Thus, further effort was concentrated on a second option for a payback mechanism: pumping groundwater in lieu of making reservoir deliveries in years when reservoir payback would be necessary.

Two sites were identified on which to conduct more refined analyses with surface and groundwater modeling tools. The GCID and Butte Basin Projects, supplied by the CVP and SWP, respectively, provided the potential to pump the largest quantity of groundwater compared to other sites, and are already well integrated with the surface water system. Under this option, conjunctive management operations would utilize wells within GCID and the Butte Basin as a backstop for more aggressive operation of Shasta Reservoir and Oroville Reservoir, respectively.

The major water surface water suppliers within the Butte Basin are WCWD, RID and Biggs-West Gridley Water District (BWGWD). BWGWD declined to participate in the investigation, so development of the Butte Basin project concentrated on the other two districts. It is noted that WCWD and RID were passive project participants meaning they provided information for the investigation but did not assume a sponsorship role.

Additionally, the Stony Creek Fan area and Orland Project was identified as a third potential project. However, upon further evaluation into potential groundwater pumping capacities and the ability to integrate the project with the Sacramento River system, it was determined that this project would not be investigated as part of this investigation. However, this project should be considered for further analysis in any future investigations.

Project site screening is discussed in additional detail in Appendix C.

4.6. Environmental Flow Objectives

A major element of this investigation was the development of specific ecological flow objectives for the Sacramento and Feather Rivers to use to formulate and evaluate reservoir re-operation scenarios. The objectives are expressed as quantitative flow targets for the two rivers, respectively, and are coupled with a dynamic decision system for prioritizing objectives from year to year. The target flows are defined in terms of magnitude, duration, frequency and seasonality, by river reach. Although developed specifically for the purpose of formulating conjunctive management strategies, the recommended objectives and flows are believed to have broader utility beyond this investigation.

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[11] Based on the most recent (Fall 2011) data collected by DWR, there appear to be some areas in the northern Sacramento Valley with persistent groundwater level declines, primarily in Glenn and Tehama Counties. These areas should be evaluated for potential groundwater banking operations in future work phases.

The general approach and rationale are briefly summarized in the following section, followed by a discussion of how the quantitative flow objectives and dynamic prioritization process are represented in the surface water model (described in Section 5). The process for developing recommended environmental flow objectives is described in detail in Appendix D.

4.6.1. General Approach and Rationale

It should be noted that the development of environmental flow regimes is as much an art as a science. However, the team attempted, to the extent possible, to use established methods to develop a transparent and replicable approach for identifying an environmental flow regime. The team conducted a detailed literature review of various methods and approaches previously utilized to develop environmental flow recommendations, and to employ a version of the holistic approach practiced in South Africa and Australia (King et. al. 2000) to identify an environmental flow regime for the Sacramento and Feather Rivers. This approach relies heavily on hydrological evaluations, previous studies and modeling analysis of historical hydrology, and expert opinion to estimate environmental flow requirements.

The approach consists of five basic steps:

1. Identify specific environmental objectives (i.e. target species, aquatic and riparian communities, and desired ecological conditions that are flow dependent).

2. Approximate the timing, magnitude, frequency, and duration (TMDF) of flows necessary to achieve identified environmental objectives.

3. Compare and analyze existing and historical hydrology to understand natural hydrologic patterns and how they have been altered.

4. Identify obvious gaps between flows necessary to achieve objectives and existing flows.

5. Modify the existing hydrograph into an environmental flow hydrograph based on an understanding of natural hydrology and the flows necessary to achieve key objectives.

Employing this approach, the team designed the environmental hydrograph to achieve the following three types of objectives.

- Geomorphic Functionality: Bed mobility, channel migration, and floodplain inundation

- Riparian Habitat Sustainability: Recruitment and maintenance of Fremont Cottonwood

- Chinook Salmon: Improved habitat, particularly rearing habitat, for all runs

The team relied on field data, modeling results, and studies, particularly the recent Nature Conservancy Study of the Sacramento River[12], to identify the minimum flows and critical thresholds to achieve each of the three types of objectives. Then historical and existing hydrology were analyzed to understand how the objectives may have been achieved under pre-dam conditions and to evaluate how existing

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[12] Sacramento River Ecological Flows Study Final Report, CALFED Ecosystem Restoration Program, The Nature Conservancy, et al, March 2008.

hydrology may fall short of meeting those objectives. The gaps identified in this manner are the basis for identifying flow objectives.

Analyses of the hydrology on both rivers reveals that the most obvious and significant change between pre-dam and post-dam eras is a sharp reduction in the magnitude and duration of the late winter and early spring hydrograph and a corresponding reduction of inundated floodplain habitat. The reduction in late winter and spring flows reduces the frequency of geomorphic and riparian flows and substantially reduces the extent and frequency of occurrence of inundated floodplain rearing habitat for salmonids. Thus, for both the Sacramento and Feather Rivers, an increase in late winter and early spring flow is the primary component of the recommended environmental flow regime, but a corresponding reduction in summer base flows is also recommended. Reduced summer flows are primarily needed to free-up water needed to restore the spring hydrograph but may also provide ecological benefits by better approximating the natural hydrograph. Reducing summer base flows could, however, increase summer temperatures and harm salmonids including the endangered winter-run Chinook salmon. On the other hand, cool water temperatures in the upper Sacramento River are largely controlled by the volume of cold water storage behind Shasta Dam and the environmental flow regime identified here does not involve modifying coldwater pool management.

The summer temperature issue is one of several key uncertainties that are inherent in establishing environmental flow targets and must be addressed before any significant modifications to the flow regime can be refined and implemented for environmental purposes. However, articulating a hypothetical environmental flow regime is the first step in identifying and addressing constraints and uncertainties associated with improving environmental flow regimes on regulated rivers. To that end, the team welcomes constructive comments and criticisms that can be used to improve upon the recommendations presented here as we learn more about the rivers and the people who depend upon them for their livelihood.

This study focuses on the magnitude and timing of flows necessary to replicate key ecological and geomorphic processes, and considers the flows necessary to provide suitable conditions for various life stages of Chinook salmon and steelhead. This study does not identify specific population targets for salmonid restoration, nor does it address important non-flow objectives such as habitat area required for restoration of target species or augmentation of coarse sediment supplies necessary to restore full geomorphic structure and function. Rather this study focuses on magnitude, pattern, and quantity of water necessary to restore ecological functions assuming that adequate physical habitat exists or will be created to complement a suitable environmental flow regime. The rationale of this focus is to identify a hypothetical environmental flow regime for the purpose of evaluating whether it is possible to reestablish ecological and geomorphic flows on the rivers of the Sacramento Basin without reducing water supply deliveries to existing water users.

Analysis of historical (pre-dam) hydrology and the habitat it created were analyzed to provide a reference point for identifying ecosystem restoration goals, recognizing that it is not possible to restore historic conditions in highly altered systems such as the Sacramento River. Historical hydrologic analysis is useful for identifying patterns in the timing, magnitude, duration, and frequency of flows that may be important for maintaining native species, but it is less useful in developing specific flow prescriptions, because physical habitat has been so profoundly changed by dams and levees and there are now competing demands for the water. We recognize that it is not possible to fully restore historical hydrology or habitat conditions in the Sacramento Valley, but ecosystem restoration will require reestablishment of a minimum threshold of both hydrologic and physical habitat conditions.

Although this study identifies hypothetical restoration flow regimes for the Sacramento and Feather Rivers, we recognize that the most reliable method for developing a restoration flow regime is through a long-term adaptive management program including a series of trials that test the effectiveness of various flow prescriptions. The hypothetical flow regime serves as a reasonable starting point for evaluating the economic feasibility of re-operating reservoirs and a long-term adaptive management program. The assumptions and uncertainties associated with the hypothetical flow regime are important to acknowledge and understand. To cost effectively achieve restoration, managers will ultimately need to test these assumptions and limit the uncertainties through an adaptive management program consisting of a combination of modeling, pilot flow studies, model calibration, and long-term implementation.

The ecologic flow objectives fall into two categories, three that were designed for Chinook salmon recovery, and one that was designed for riparian habitat recovery. These may be summarized as follows:

For Chinook salmon:

- Geomorphic objectives: Sediment transport, bed mobilization and bed scour; channel migration and floodplain processes; inundation and fine sediment deposition

- Floodplain inundation objectives : inundated floodplain habitat for rearing juveniles during the later winter and early spring; maintain and recruit spawning habitat, but avoid scouring gravels while eggs or alevon are present

- Spring pulse flow objectives: Suitable flow conditions and temperatures for all life stages;

For Riparian Habitat:

- Fremont cottonwood seedbed preparation, seed germination and seedling growth; periodic large-scale disturbance of the riparian zone; riparian stand structure and diversity

4.6.2. Representing Environmental Flow Objectives in the Surface Water Model

The different flow objectives developed for the Sacramento and Feather Rivers are simulated as all-or-nothing thresholds, meaning that a decision to satisfy an objective is made only if the full target flow can be sustained for the specified duration. As discussed in Appendix D, environmental objectives are based on the magnitude and duration of flows required to replicate certain ecological and geomorphic processes. Environmental objectives are specified and prioritized by water year type. The Sacramento River Water Year Type Index (Sacramento River Index), sometime referred to as the 40-30-30 Index, is used to classify each year as either wet, above normal, below normal, dry, or critical.

Each of the environmental flow objectives is described quantitatively below.

4.6.2.1. Geomorphic Flow Objectives

Geomorphic releases are short-duration, high-flow events for the purpose of sediment transport, channel migration, and flood plain processes, such as inundation and fine sediment transport. Geomorphic releases are targeted from March through April and are only required to last several hours. The surface water model simulates geomorphic events lasting one day due to the ramping requirements when making these large releases from reservoirs. Table 4-2 presents geomorphic flow objectives for Sacramento and Feather Rivers.

TABLE 4-2
Geomorphic Flow Objectives for Sacramento and Feather Rivers
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Sacramento River Index	Sacramento River (cfs)	Feather River (cfs)
Wet	105,000	50,000
Above Normal	85,000	35,000
Below Normal	65,000	20,000
Dry	35,000	10,000

No objective specified in critical year types.

4.6.2.1. Riparian Establishment

The purpose of riparian establishment flows is to recruit and grow cottonwoods in the riparian areas along the rivers. Riparian establishment flows are designed to assist in several phases of early cottonwood growth including seedbed preparation, seed germination, and seedling growth. These flows also create periodic large-scale disturbances of the riparian zone. Riparian establishment objectives (see Figure 4-3) are specified for the period of mid-April through mid-June to coincide with the cottonwood reproductive cycle. Riparian recruitment flows are large-magnitude flows for extended periods of time and are typically only possible during years of above average runoff. Therefore these objectives are only specified in years classified as wet or above normal by the Sacramento River Index.

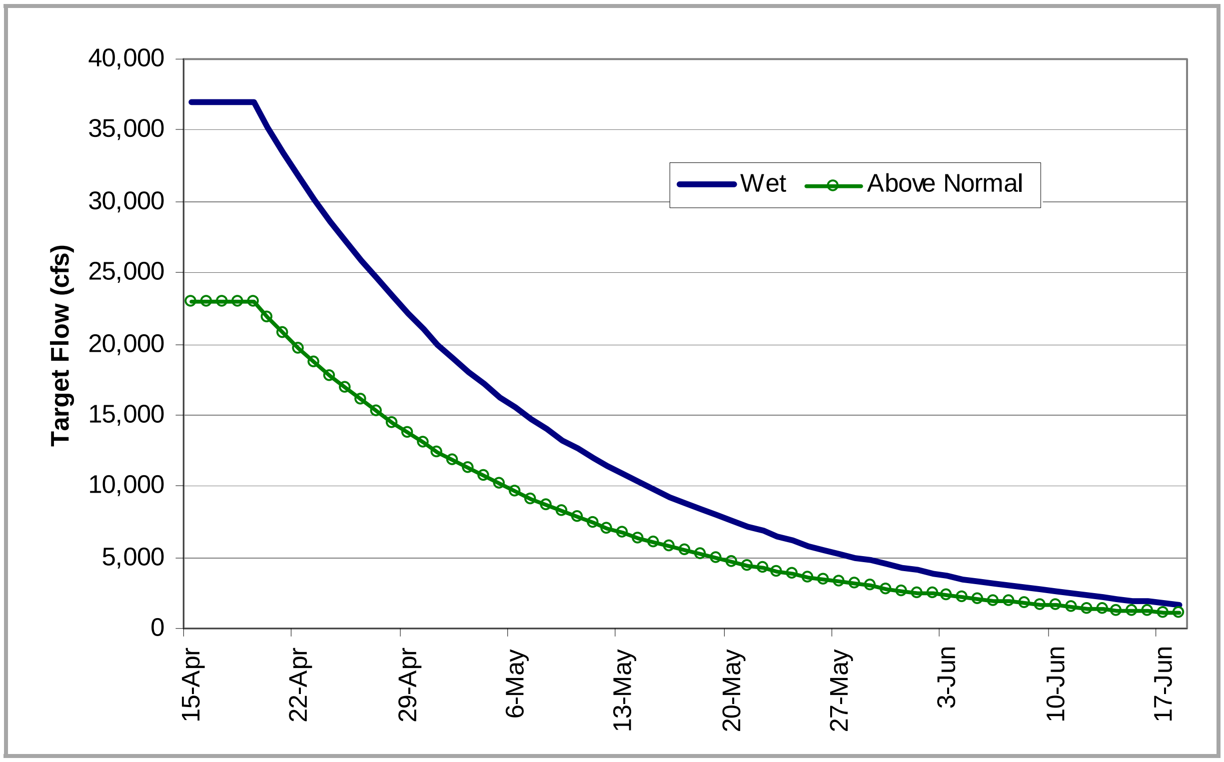

FIGURE 4-3
Sacramento River Riparian Establishment Objective
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Figure 4-3 illustrates the shape of the of riparian establishment objectives. The objective begins with a high-flow event held for a period of 5 days followed by a 60-day recession limb when the target each day is 5 percent less than the previous day's target. Table 4-3 summarizes the objectives for both the Sacramento and Feather Rivers.

4.6.2.2. Spring Pulse Flows

Spring pulse flows are designed to simulate a portion of the historic unimpaired runoff of the river to help create suitable flow conditions and temperatures for Chinook salmon migration. These flows also are designed to help maintain and recruit spawning habitat and avoid scour when eggs are in redds. Spring pulse flow targets are specified in all but critical year types, though the magnitude and duration of the target is reduced in years with less runoff. Tables 4-4 and 4-5 summarize the spring pulse objectives.

4.6.2.3. Flood Plain Inundation

Inundation of the Sutter and Yolo Flood Bypass channels is another environmental objective. It is assumed for this study that the weirs that currently block flow into the bypasses below certain river stages can be modified to allow inundation at lower river stages and flows. Inundation of the flood bypasses provides rearing habitat for juvenile salmonids. These inundation flows are targeted to correspond with outmigration of salmonids in the spring months and designed to last for 45 days. Flood plain inundation flows can be set for one of three different time-periods in the surface water model: February 15 to March 30, March 1 to April 15, or March 15 to April 30. Table 4-6 presents flood inundation objectives for Sacramento and Feather Rivers.

TABLE 4-3
Riparian Establishment Objectives
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Sacramento River Index	**Sacramento River**		**Feather River**	
	5-day Flow (cfs)	**Recession Rate**	**5-day Flow (cfs)**	**Recession Rate**
Wet	37,000	5%	12,000	5%
Above Normal	23,000	5%	10,000	5%

Note: No objective specified in below normal, dry, or critical year types

TABLE 4-4
Sacramento River Spring Pulse Objective
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Sacramento River Index	**Flows (cfs) by Date**					
	3/15-3/31	**4/1-4/14**	**4/15-4/30**	**5/1-5/14**	**5/15-5/31**	**6/1-6/14**
Wet	14,000	14,000	14,000	14,000	14,000	8,500
Above Norm	12,500	14,000	14,000	14,000	8,500	
Below Norm	12,500	12,500	12,500	8,500		
Dry	10,000	12,000	12,000	8,500		

Note: No objective specified in critical year types

TABLE 4-5
Feather River Spring Pulse Objective
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Sacramento River Index	Flows (cfs) by Date					
	3/1-3/14	**3/15-3/31**	**4/1-4/14**	**4/15-4/30**	**5/1-5/14**	**5/15-5/31**
Wet	8,000	12,500	12,500	11,000	6,000	4,000
Above Norm	6,500	6,500	10,000	10,000	5,000	3,000
Below Norm	3,200	3,200	8,000	8,000	3,200	
Dry	2,700	2,700	5,500	5,500	2,700	

Note: No objective specified in critical year types

TABLE 4-6
Flood Plain Inundation Objective for Sacramento and Feather Rivers
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Sacramento River Index	Sacramento River at Fremont Weir (cfs)
Wet	45,000
Above Normal	35,000
Below Normal	35,000
Dry	35,000

Note: No objective specified in critical year types

4.6.2.4. Prioritization of Environmental Flow Objectives and Decision Month

Environmental objectives are prioritized based primarily on hydrologic year type and the frequency with which the various objectives are satisfied. Considering the frequency of when objectives have been satisfied places higher priority on objectives that have not been met in recent years relative to those that have. For example, if the spring pulse objective is typically the highest priority in an above normal year but was met in the previous year (either in the base condition or with a project release) it may be desirable to shift the highest priority to the flood plain inundation objective instead.

To implement this dynamic prioritization scheme that shifts the priority from one year to the next depending on year type and occurrence interval a user-specified relative priority value is combined with the number of years since an objective was last satisfied to determine the final priority of objectives each year.

Table 4-7 contains the relative priority matrix developed by the project team for use in the surface water model. Lower numbers denote higher priorities.

Final priority is determined by subtracting the relative priority from the number of years since the objective was met and comparing the results for all objectives.

Table 4-8 provides an example prioritization calculation for a hypothetical wet year on the Feather River system.

TABLE 4-7
Relative Priority Matrix for Environmental Objectives
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Sacramento River			Both Rivers	Feather River		
Sacramento River Index	**Geomorphic**	**Riparian Recruitment**	**Spring Pulse**	**Flood Plain Inundation**	**Geomorphic**	**Riparian Recruitment**	**Spring Pulse**
Wet	10	2	10	10	10	2	10
Above Normal	15	6	2	4	15	5	2
Below Normal	2	99	1	3	2	99	1
Dry	5	99	2	90	5	99	2
Critical	80	99	1	90	80	99	1

TABLE 4-8
Example Prioritization of Environmental Objectives, Feather River, Wet Year
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Flood	Geo	Rip.	Spring
Years Since Met	6	1	4	25
Relative Priority	10	10	2	10
Final Priority	-4	-9	2	15

The objectives are prioritized by descending final priority scores, as follows: Spring Pulse, Riparian Recruitment, Flood Plain Inundation, and Geomorphic. In this example, because it had been 25 years since the spring objective had been met, Spring Pulse became the first priority objective, though its relative priority was lower than the Riparian Objective.

A decision must be made each spring to determine which objectives the model will attempt to meet that year. Several of the environmental objectives have variable start times and durations. To avoid always meeting the objective that starts earliest in the year or miss meeting an objective in hopes of satisfying a future objective, a user-specified decision month is used in the model. Project assets, water costs, and prioritization of environmental objectives are all determined during the decision month and results are used for operations that year. The decision month is used to determine what objectives the model will attempt to meet each year.

4.7. Agricultural Water Supply Objectives

As previously mentioned, historical agricultural water supply shortages in the Sacramento Valley were used to represent the targets for water supply enhancements. Specifically, for the CVP/Sacramento River, unmet demands of CVP contractors within the Tehama-Colusa Canal Authority (TCCA) were used to represent additional demands. Members of the TCCA, including contractors supplied from the Corning Canal, hold agricultural service contracts for approximately 320 TAF of contract supply from the CVP. Annual allocations to CVP contractors are simulated in CalSim II based on forecasted reservoir inflows, reservoir storage conditions, and the ability to deliver water. Simulated allocations range from 0 to 100 percent of full contract supply. When simulated allocations are less than 100 percent, it is assumed that the difference between simulated allocations and full contract supply is an unmet agricultural demand within the TCCA.

Figure 4-4 illustrates the annual unmet agricultural demand as a function of simulated allocations to the TCCA for each year of the study. The annual unmet demand illustrated in Figure 4-4 was assumed to occur on a typical agricultural demand pattern during the irrigation season.

On the Feather River system, the majority of SWP contractors have reliable water supplies with the exception of a few small contractors. There are no existing SWP contractors with large, frequently unmet agricultural demands in the Butte Basin. Therefore a more general unmet agricultural demand was defined for the Feather River based on user input and judgment. Table 4-9 summarizes the assumed unmet agricultural demand that could be met from Feather River supplies for purposes of modeling.

Figure 4-5 illustrates the annual volume of demand based on the assumptions in Table 4-9.

It should be noted again that the estimates of unmet agricultural demands described above are regarded as surrogates for any type of water supply need that might be identified for the Sacramento and Feather River systems.

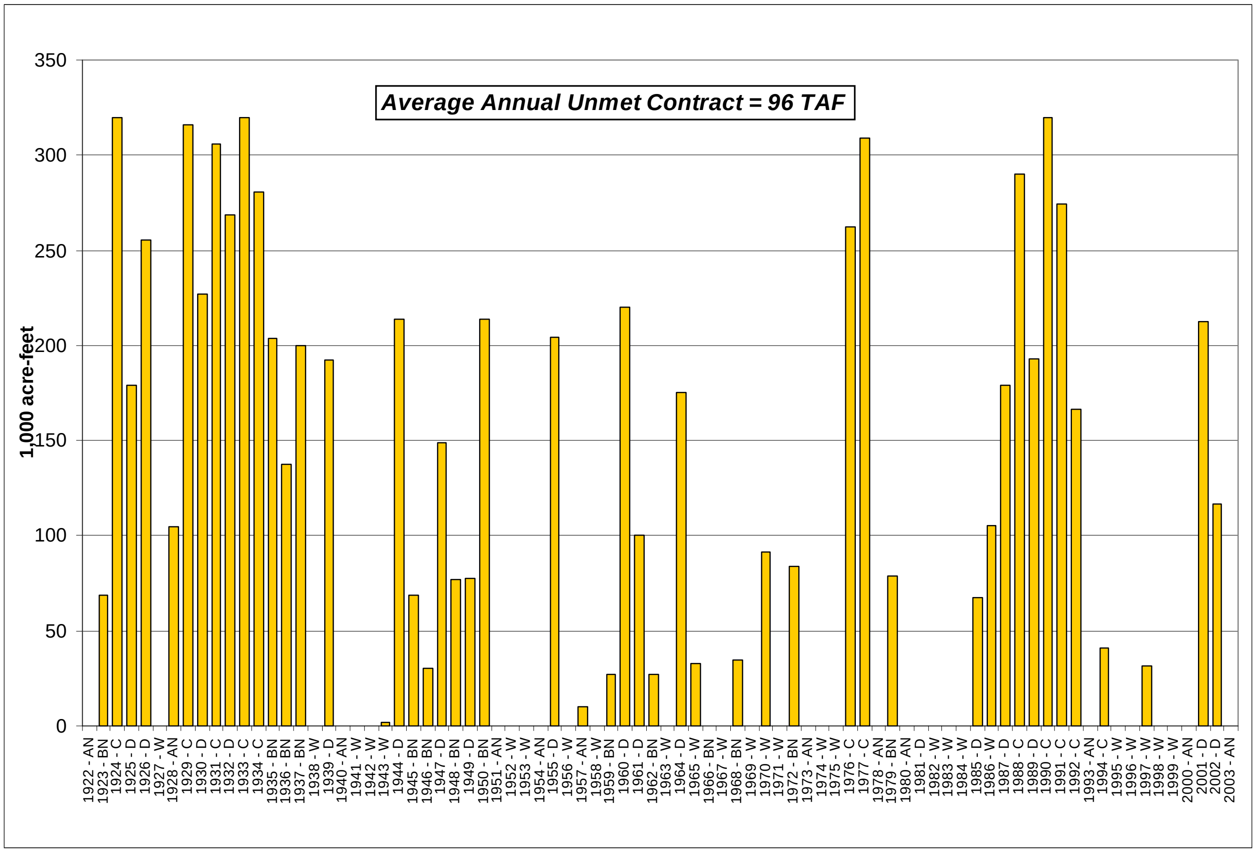

FIGURE 4-4
Unmet Agricultural Demand within TCCA Service Area
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

TABLE 4-9
Assumed Unmet Agricultural Demand within the Feather River System
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Sacramento Valley Index	**Unmet Agricultural Demand (TAF)**
Wet	0
Above Normal	40
Below Normal	75
Dry	90
Critical	100

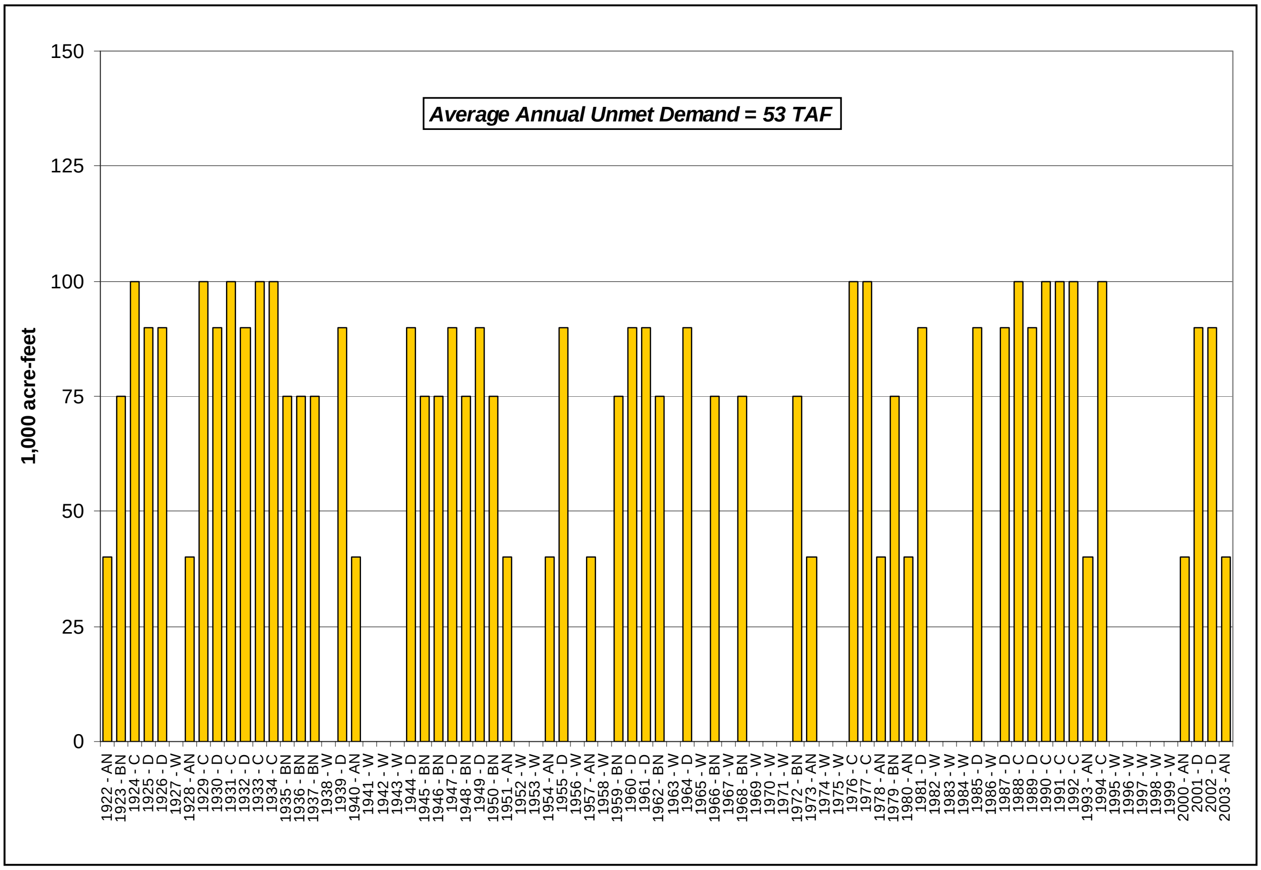

FIGURE 4-5
Assumed Unmet Agricultural Demand within Feather River System
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

5. Development and Assessment of Initial Project Scenarios

5.1.Initial Project Scenarios

Four conjunctive operations scenarios were developed for the GCID and Butte Basin project locations for initial analysis. The scenarios are differentiated primarily by the following two parameters:

- Maximum Payback Capacity. This is the maximum volume of groundwater pumping that would occur in any year within the pumping period (see below) in GCID and the Butte Basin, respectively. This capacity essentially establishes the scale of the conjunctive operation, since the water deficit in the reservoirs cannot exceed the capacity to repay it, when it becomes necessary. Maximum capacities were based primarily on professional judgment taking into consideration historical pumping in the two areas and average pumping intensity (acre-feet per acre). The payback capacities selected for analysis were:
  - 100 TAF in GCID and 50 TAF in Butte Basin; total 150 TAF
  - 200 TAF in GCID and 100 TAF in Butte Basin; total 300 TAF

- Pumping Period. Pumping must occur when there is a demand for water that would otherwise be satisfied by reservoir releases. In both project areas, the dominant crop is rice, which is typically planted between mid-April and early June and harvested in September. Following harvest, most rice fields are re-flooded between September and November for rice straw decomposition and to create waterfowl habitat. Thus the water delivery season in both areas is from mid-April through November. Based on this, three pumping periods listed below were identified for analysis. Different pumping periods were evaluated primarily to reveal differences in aquifer response to differences in the timing and rate of pumping. Additionally, the pumping period affects the capital investment needed for pumping facilities.
  - “Summer” defined as May through August
  - “Fall” defined as September through November
  - “Summer and Fall” defined as May through November

The combinations of payback capacity and pumping periods selected to form scenarios are listed in Table 5-1.

TABLE 5-1
Project Scenarios Evaluated
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Scenario	GCID Annual Pumping Capacity	Butte Basin Annual Pumping Capacity	Pumping Season
1	100 TAF	50 TAF	Summer (May through August)
2	200 TAF	100 TAF	Summer (May through August)
3	100 TAF	50 TAF	Fall (September through November)
4	100 TAF	50 TAF	Summer and Fall (May through November)

TAF = thousand acre-feet

Additionally, two well field configurations were evaluated for each scenario, one corresponding to existing wells screened at depths between 100 to 500 feet and a second well field corresponding to new wells screened at depths of 900 to 1,100 feet. Thus a total of eight operational scenarios were evaluated.

The well field configurations corresponding to the different payback capacities and pumping depths are illustrated in Figures 5-1 through 5-4.

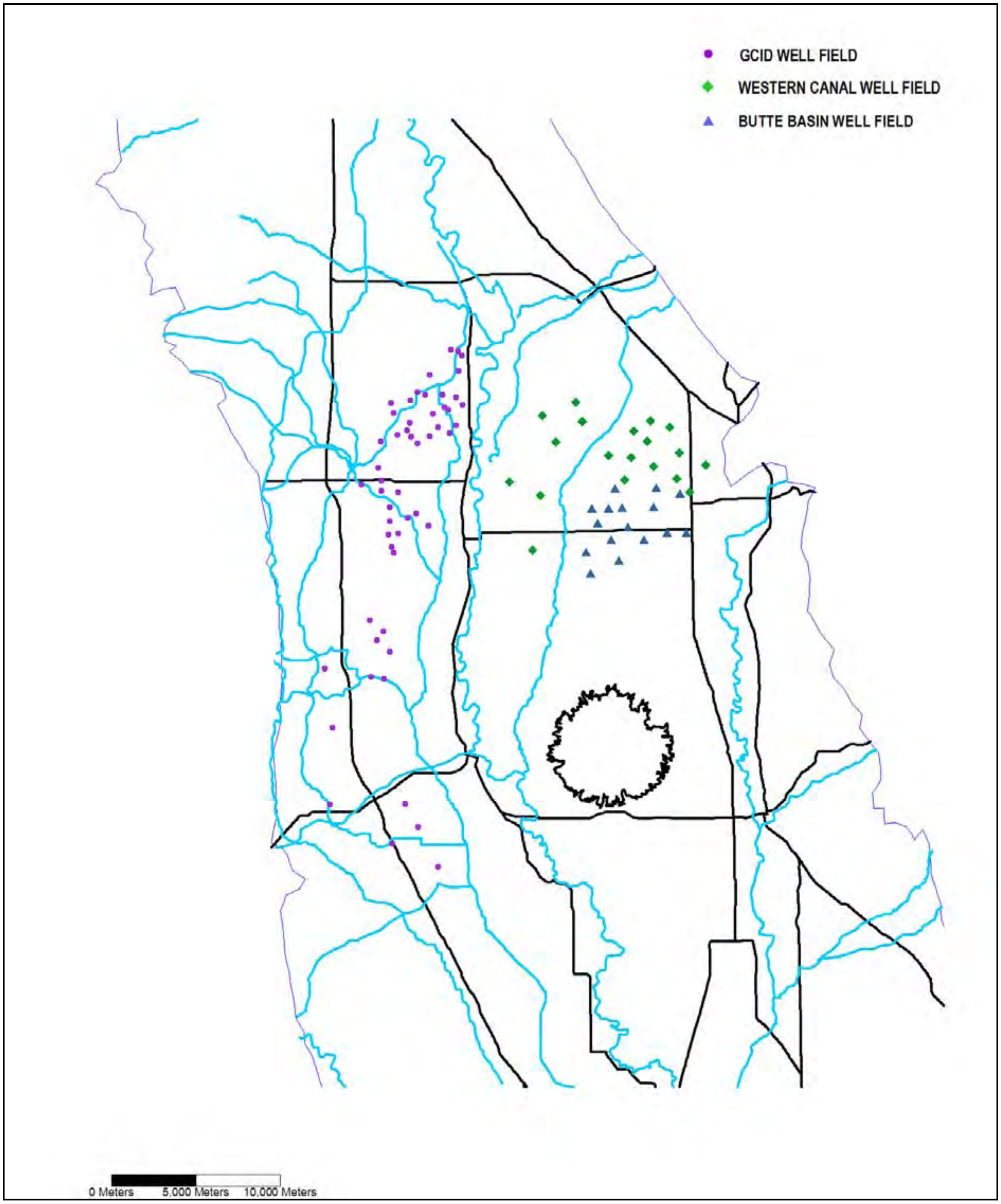

FIGURE 5-1
Existing Well Locations, 100 TAF GCID And 50 TAF RID and WCWD Well Field
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

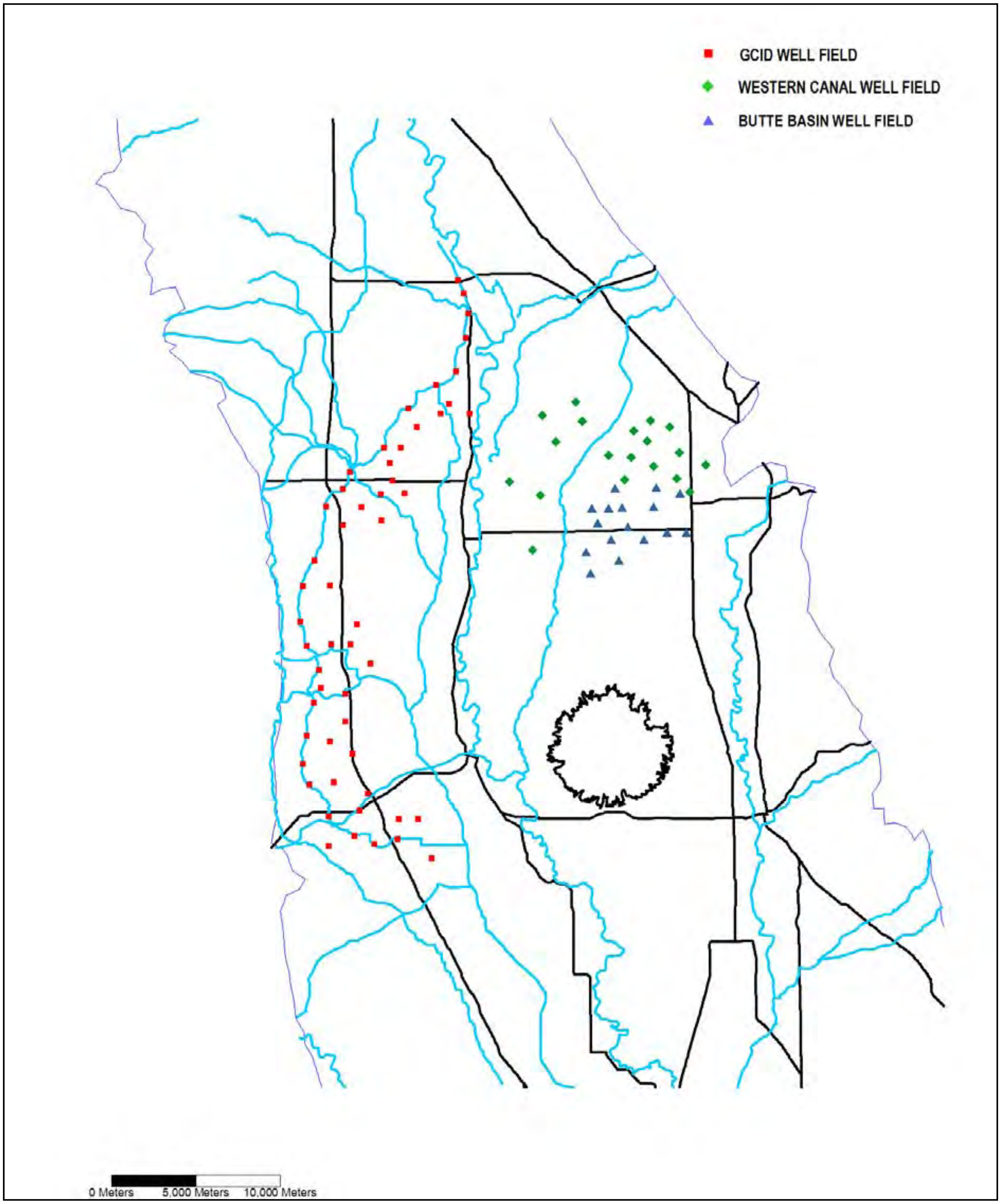

FIGURE 5-2
New Well Locations, 100 TAF GCID and 50 TAF Butte Basin Well Fields
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

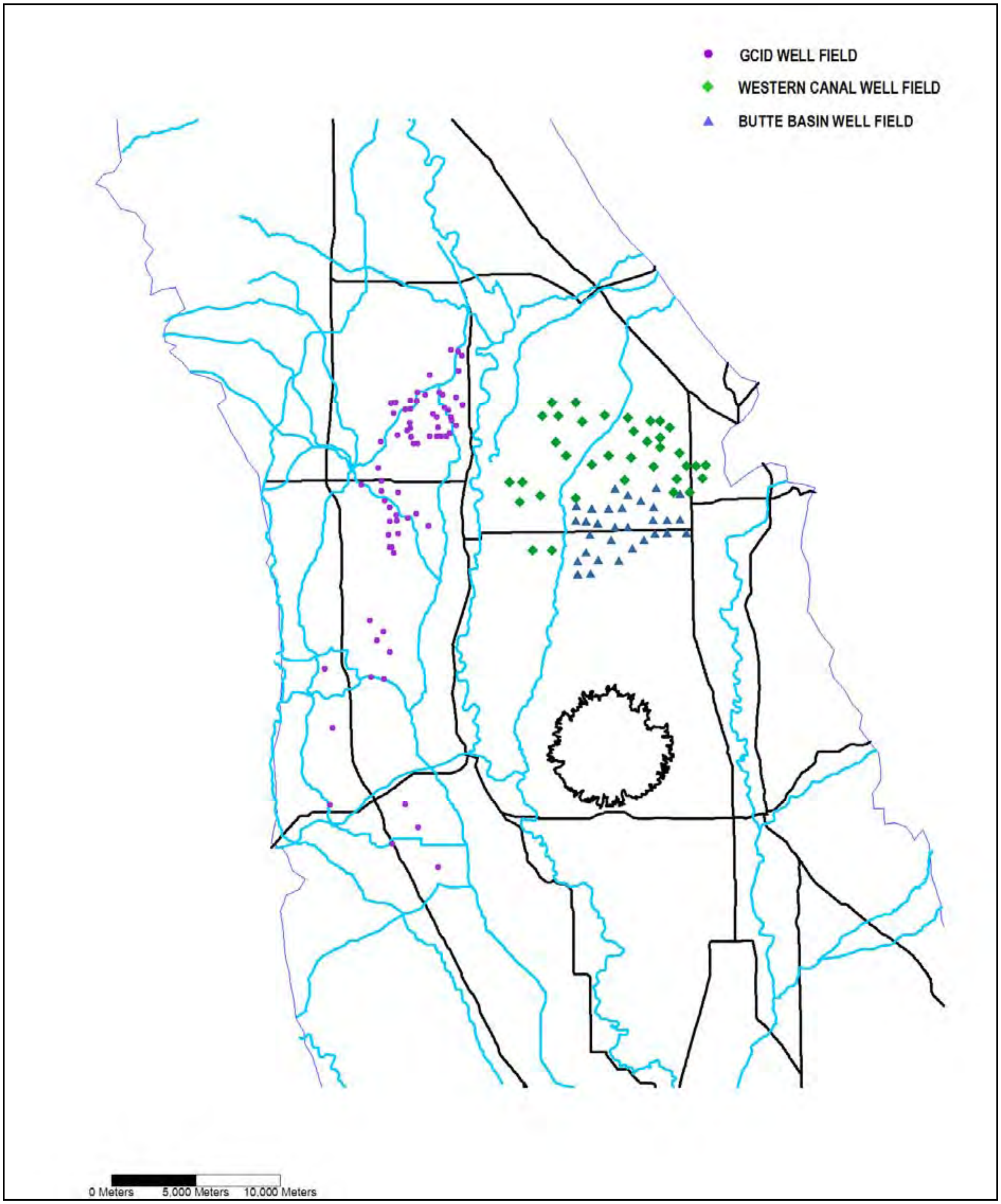

FIGURE 5-3
Existing Well Locations, 200 TAF GCID and 100 TAF Butte Basin Well Fields
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

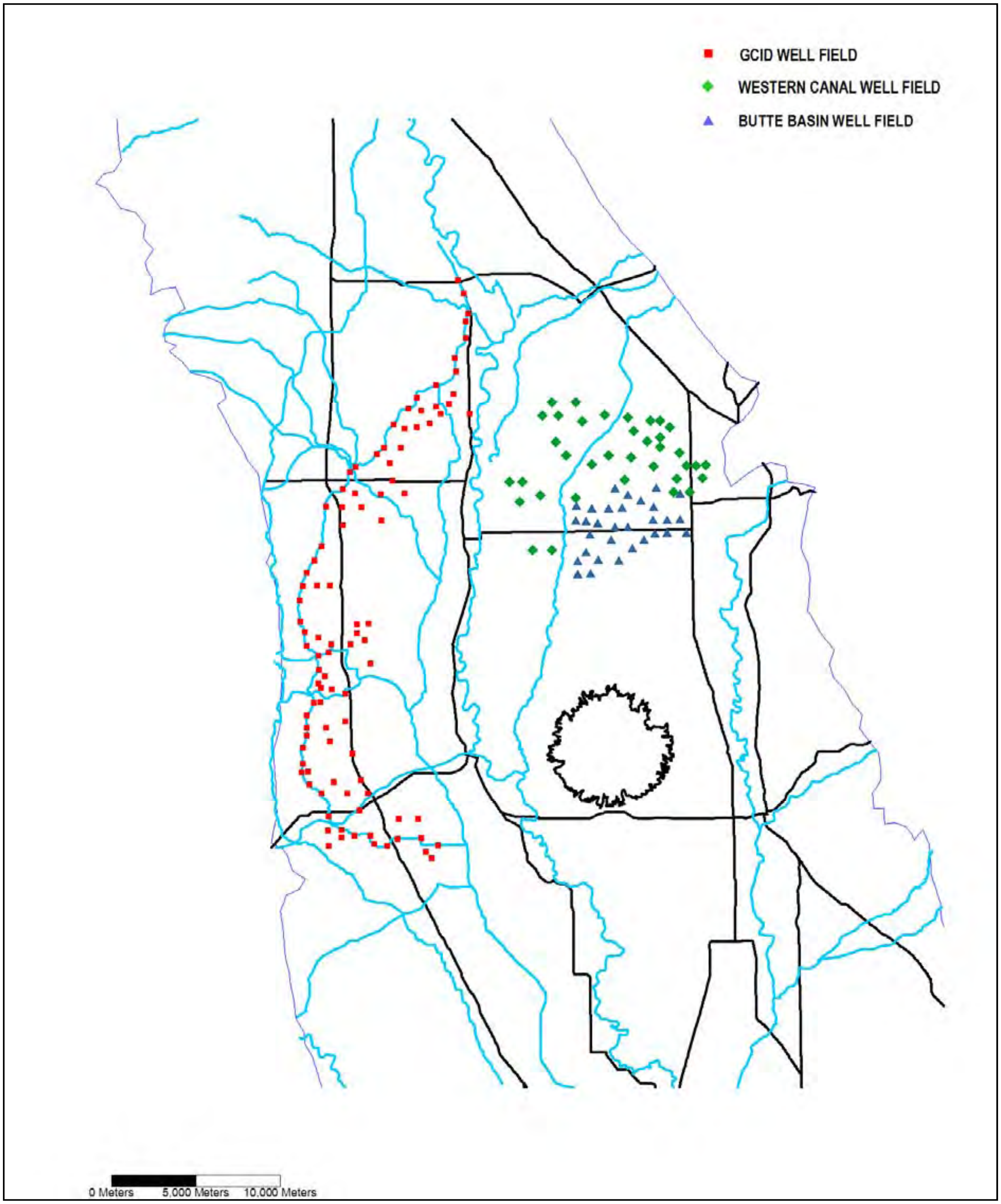

FIGURE 5-4
New Well Locations, 200 TAF GCID and 100 TAF Butte Basin Well Fields
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

5.2.Initial Model Approach and Development

5.2.1. Overview

Formulating and evaluating potential conjunctive management projects requires simulation of both surface water and groundwater systems. Simulating the surface water system is necessary to determine when water is available to refill reservoirs and estimate unmet agricultural demands, environmental objectives, and flow conditions. A groundwater model is necessary to estimate the effects of additional pumping on aquifer systems, including the spatial extent and magnitude of drawdown and potential change in stream-aquifer interaction. Changes in stream-aquifer interactions may affect the surface water system, depending on stream conditions when the changes occur. For example, if additional pumping results in more stream loss to the aquifer or less aquifer contribution to stream flow during the winter season of relatively wet years when the surface water system has surplus flow, there may be little or no impact. However, if pumping reduces stream flow during months and years when the surface water system is being operated to meet specific flow or water quality requirements, any reduction in stream flow will require a corresponding increase in reservoir release to ensure the flow requirement continues to be met. This decreases the water supply benefit of conjunctive management projects. Evaluating this aspect of conjunctive management projects requires interaction between surface water and groundwater models.

The main tool used to evaluate alternative conjunctive management operations strategies and test alternative environmental flow thresholds and priorities is a spreadsheet-based surface water model (Figure 5-5). It is set up to simulate changes in operation of Lake Shasta and Lake Oroville relative to conditions depicted in a baseline CalSim II simulation of CVP and SWP operations. The CalSim II baseline provides time series of reservoir storage levels, stream flows, and water deliveries which are used by the surface water model. Conjunctive management operations are simulated and layered onto baseline operations based on user inputs, while maintaining compliance with existing CVP and SWP rules, regulation, and operations.

The surface water model is configured by defining target river flows through specification of environmental objectives and inputting other user-defined parameters, including groundwater (payback) pumping capacity, reservoir operations objectives and constraints and other factors. The groundwater model is not operated for each surface water model run because it is much more computationally intensive and takes much longer to run. Instead, the groundwater model was used to develop functions that describe general surface water-groundwater interactions. These functions reside in the surface water model and are used to account for increases in stream leakage caused by project pumping that must be offset by additional project releases under certain conditions. This approach allows quick testing and evaluation of alternative conjunctive operations scenarios without having to make matching groundwater model runs.

The groundwater model was used to evaluate the particular scenarios previously described with respect to changes in groundwater levels and stream leakages caused by additional groundwater pumping. This was done by simulating the time series of project pumping determined through the surface operations simulations in the groundwater model.

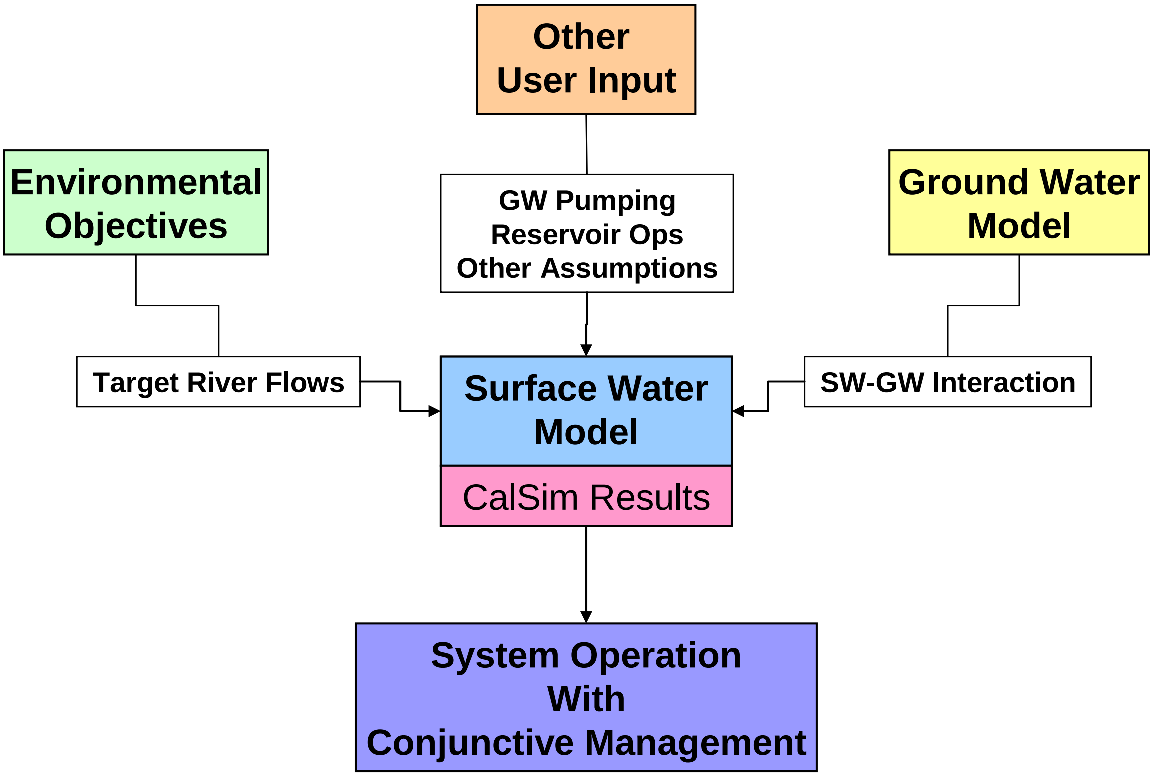

FIGURE 5-5
Surface Water Model Inputs and Operations
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

5.2.2. Surface Water Model

The surface water model includes a forecast of fall storage conditions based on current reservoir storage, runoff forecasts, and an estimate of reservoir releases from the current month through September[13]. The model simulates risk associated with making decisions based on imperfect information. Runoff forecasts at different exceedance levels are used during the spring with more conservative forecasts, 99 or 90 percent exceedance, used in February and March, respectively. A method to estimate reservoir release volumes was developed for Shasta and Oroville by correlating simulated CalSim II releases with a system-wide CVP water supply index and SWP allocations, respectively. The CVP water supply index is the sum of current storage in Trinity, Shasta, Folsom, and CVP San Luis plus runoff forecasts on the Sacramento and American Rivers, plus Kings River flow to Mendota Pool. The CVP water supply index and runoff forecasts for the Sacramento, Feather, and American Rivers are the same as used in CalSim II for simulation of CVP/SWP operations. Initial correlations were developed and adjusted to balance how forecasted storage compared with CalSim II simulated storage across various year types.

The surface water model treats the groundwater system as a source of water and does not simulate groundwater flows or conditions. It does, however, include features to account for estimated effects of groundwater pumping on stream flow accretion and depletion through use of functions derived from

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[13] This methodology for forecasting fall reservoir storage was added as part of model refinements made in response to suggestions provided by CVP and SWP operators (see Section 6). For the initial analysis, the model used future (September) reservoir storage levels to make project operation decisions.

complementary simulations of pumping in the groundwater model. These functions provided a coarse but adequate representation of stream-aquifer interaction so that the surface water model could be used for gaming sessions without having to operate the groundwater model. Final scenarios were evaluated using actual changes in stream-aquifer interaction based on complimentary groundwater model simulations.

5.2.3. Groundwater Model

Numerous improvements were made to previously existing modeling tools, and new tools were developed for this analysis of conjunctive management projects. For the groundwater analysis, an existing simplified groundwater modeling tool was completely re-designed and improved, to yield a powerful analytical package now referred to as the Sacramento Valley Groundwater Model (SACFEM). The basis for the SACFEM model was a simplified superposition-based groundwater model previously developed to support the Sacramento Valley Water Management Program. That model represented a very simplified depiction of the Sacramento Valley aquifer system as no recharge components to the aquifer system (deep percolation of precipitation and applied water) or discharge components (regional agricultural pumping) were included, and therefore the model could only compute the incremental change in groundwater levels and streams flows during the irrigation season. It was assumed that the aquifer system fully re-filled every winter, and each year of pumping was independent of previous aquifer stresses.

The SACFEM model is a full water budget based transient groundwater flow model that incorporates all of the groundwater and surface water budget components on a monthly time step over the period of simulation. This model provides very high resolution estimates of groundwater level and streamflow effects due to conjunctive water management pumping across the valley.

The surface water model is a new tool designed specifically to analyze conjunctive management projects for agricultural and environmental benefits. Its flexibility for use in gaming sessions and for sensitivity and tradeoff analysis helped provide understanding of conjunctive management concepts, operations, and limitations.

The integration of surface water and groundwater modeling tools and the simulation of effects of additional groundwater pumping on the surface water system is a significant advancement over previous modeling tools. Simulation of changes in stream-aquifer interaction, the spatial and temporal variations in those changes, and conditions in the surface water system when changes occur are key components for evaluating conjunctive management projects and understanding their benefits and risks.

Development and calibration of the surface water and groundwater models used to develop and analyze the project scenarios is documented in detail in Appendix B.

5.2.4. Surface and Groundwater Model Interaction

As previously mentioned, evaluation of conjunctive management projects requires simulation of both surface water and aquifer systems. However, regional groundwater models with the needed level of refinement to adequately simulate pumping projects require run times that prohibit their use in gaming situations and for quickly evaluating multiple scenarios. Therefore, the surface water and groundwater model were used in an iterative fashion to simulate conjunctive management operations in both systems (see Figure 5-6).

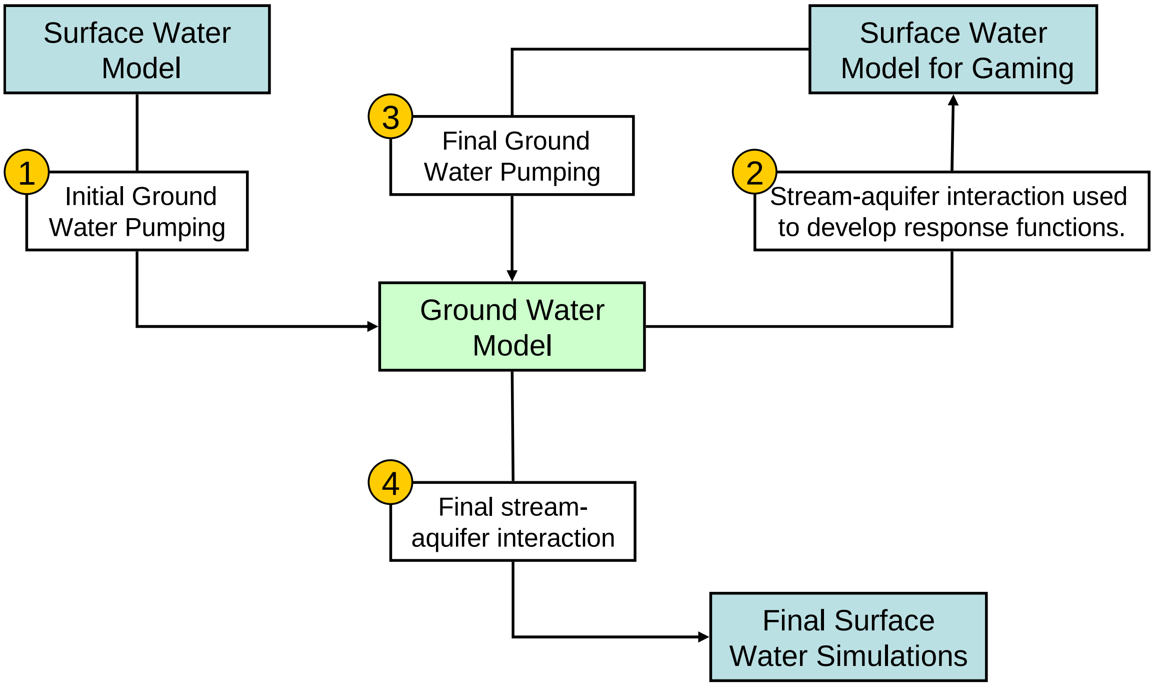

FIGURE 5-6
Surface Water and Groundwater Model Interaction
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

An initial surface water model was developed to simulate project operations and develop the time series of groundwater pumping at each project site. Pumping time series were simulated in the groundwater model and results were reviewed, including changes in stream-aquifer interactions. These initial changes were used to develop response functions for use in the gaming model to quickly approximate changes in stream-aquifer interaction when simulating various conjunctive management operations.

Response functions were used during the gaming sessions and when conducting tradeoff analyses to determine the final project scenarios. Pumping time series from the final project scenarios were then provided to the groundwater model for final simulation and resulting changes in stream-aquifer interactions associated with the pumping schedules were input back into the final surface water simulations.

5.2.5. Qualifications

Modeling analyses were performed at a planning level to help prove concepts and define conjunctive management projects and operations. Analyses were conducted for general projects, locations, and operations. More specific and refined analyses will be required as specific projects are defined. Most analysis was conducted in a comparative, rather than absolute, manner and results must be interpreted as such.

Additionally, mathematical modeling tools typically report results at a level of precision that exceeds their level of accuracy. For example, planning-level surface water models may provide estimates of water supply accurate to within a range of several thousand acre-feet, but results with a precision down to an acre-foot. Model results presented in subsequent sections are rounded to levels of precision appropriate for comparison with results from other scenarios. Planning-level modeling tools used in this analysis are not necessarily accurate to this level.

5.3.Performance of Initial Scenarios

The performance of each of the initial scenarios is summarized in this section in terms of the effects of project operations on the surface water system including reservoir storage, the frequency and magnitude of environmental flow and water supply releases and reservoir refill. Scenarios 1, 3 and 4 all have the same effects on the surface water system because they have the same payback pumping capacity. (Scenarios 1, 3 and 4 are differentiated by pumping season, not by pumping volume; therefore, each scenario has its unique effects on groundwater conditions.) Scenario 2 has different effects because it has a different payback capacity. The material presented here is also presented and discussed in greater detail in Appendix B.

5.3.1. Scenarios 1, 3 and 4 – Shasta Reservoir and Sacramento River

Scenarios 1, 3 and 4 are defined by maximum seasonal groundwater pumping capacities of 100 TAF in GCID and 50 TAF in the Butte Basin. Environmental objectives and unmet agricultural demands are as presented in preceding sections. The model first determines ability to meet environmental objectives and then uses remaining project assets to meet agricultural demands. Sensitivity to prioritization of environmental objectives and agricultural demands was evaluated and is explained in subsequent sections of this report.

The following series of plots summarize the annual operations with conjunctive management. The first series of plots summarize Sacramento River and Shasta Reservoir operations and the second series summarize Feather River and Oroville Reservoir operations. Plots are arranged in order of how operations occur each year. In winter and spring months, additional water is released from reservoirs to satisfy environmental objectives. During summer months additional water is released to meet agricultural demands. The result is that fall reservoir storage levels are lower than they would be under operations without conjunctive management projects, as shown on Figure 5-7. Reservoir storage space is typically refilled with surplus surface water during subsequent winter and spring periods. If reservoirs do not refill with surplus surface water and fall reservoir storage levels are forecasted to be low, reservoirs are refilled by pumping groundwater in conjunctive management projects and holding a similar volume of surface water in the reservoir.

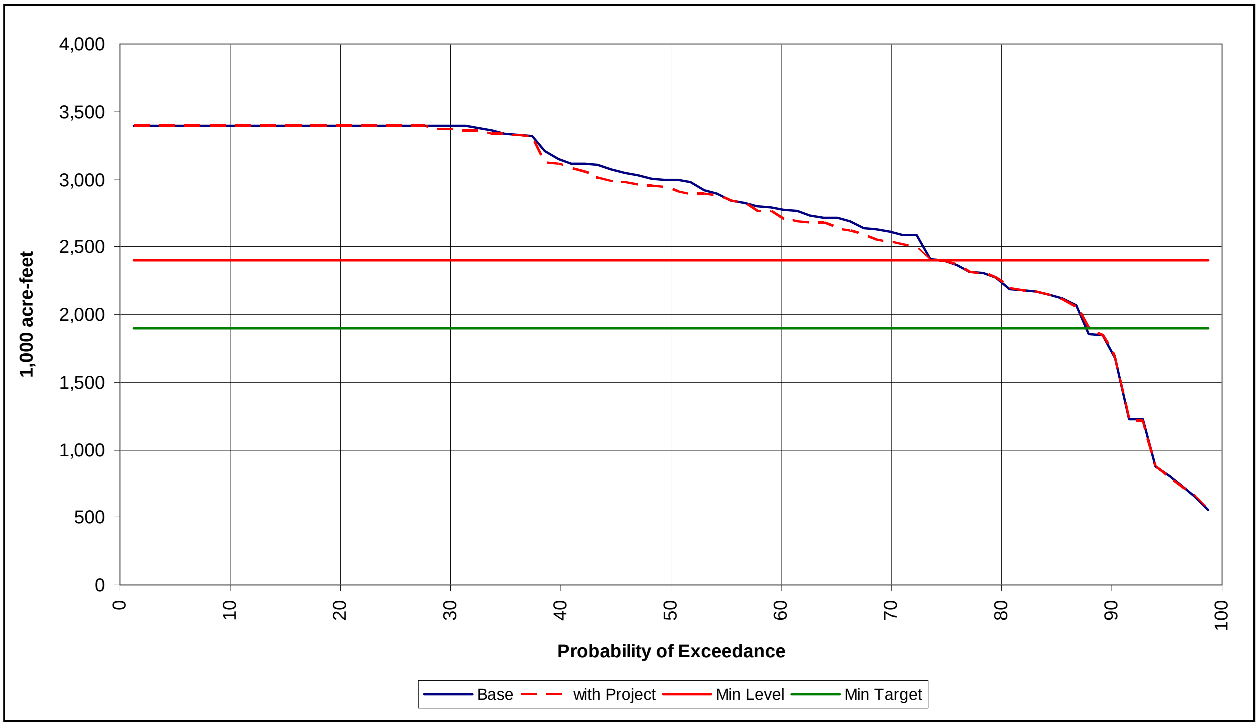

FIGURE 5-7
Shasta Reservoir September Storage Exceedance Probability with Conjunctive Management, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Figure 5-8 illustrates annual volumes of water released to satisfy various environmental objectives on the Sacramento River. Color-coded bars and the legend refer to relative priority of objectives in each year. For example, in 1928 the red bar indicates that water was released to meet objective 4, the lowest priority objective. The type of objective, either geomorphic (Geo), riparian recruitment (Rip), spring pulse (Spring), or flood plain inundation (Flood) is labeled above the corresponding bar. Geomorphic objectives are met most frequently due to lower water costs associated with the short duration objective. Average annual release for environmental objectives is 13 TAF.

Figure 5-8 shows only years when environmental objectives are met through project release. Environmental objectives are also met at times under existing (baseline) system operation. This information is summarized in Table 5-2. For the flood plain inundation objective, the project includes modifications to the Freemont Weir to allow inundation with less Sacramento River flow than is required under existing conditions. The existing Fremont Weir crest limits inundation of the Yolo Bypass for flows less than approximately 62,000 cfs. The project assumes it is possible to modify the weir to allow inundation with flows of approximately 35,000 cfs. Therefore this objective can be met by the project, either under base condition flows between 35,000 and 62,000 cfs (flows in excess of 62,000 cfs meet the objective in the base condition) or through additional reservoir release to create flows of approximately 35,000 cfs.

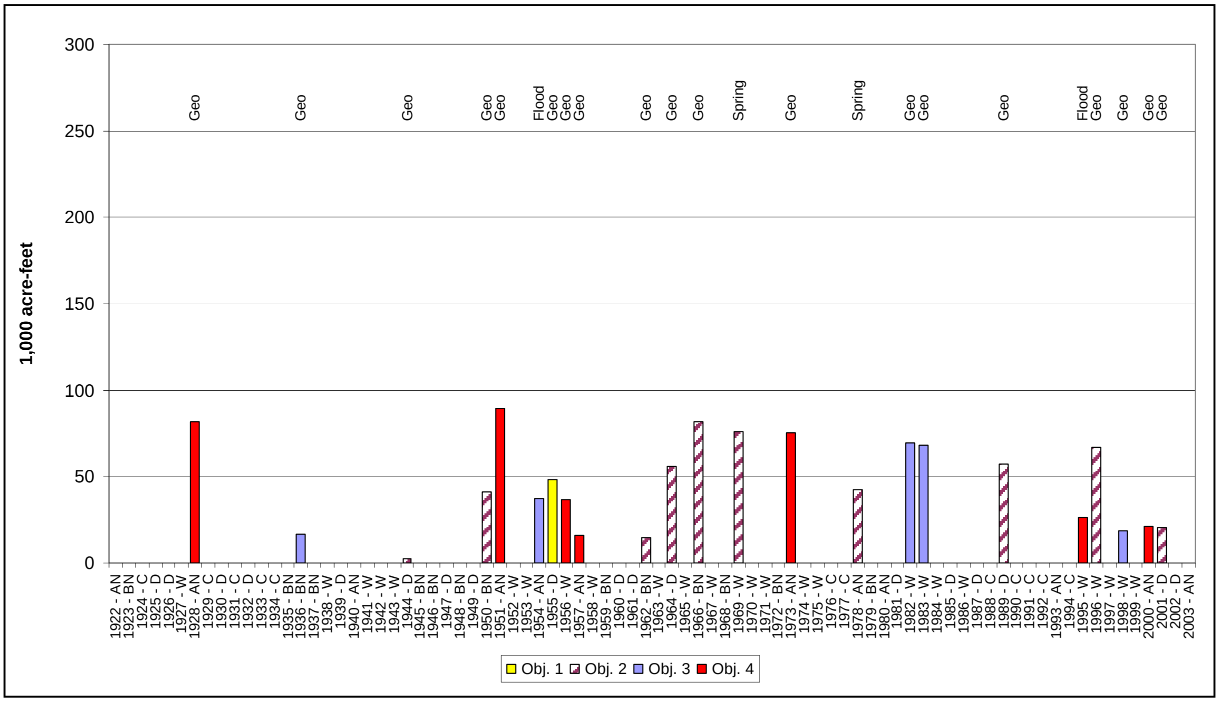

FIGURE 5-8
Sacramento River Environmental Objectives Met with Conjunctive Management, Scenarios 1, 3 And 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

TABLE 5-2
Number of Years Sacramento River Environmental Objectives are Met, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Objective	Met with Base Conditions Flows	Met with Project Flows	Total
Spring Pulse	5	2	7
Riparian Recruitment	0	0	0
Geomorphic	25	18	43
Flood Plain Inundation	21	20	41

Table 5-2 show the flood plain objective is met in 20 years with the project, though there are only 2 years with releases for this objective illustrated on Figure 5-8. This indicates that the objective was met with base condition flows between 35,000 and 62,000 cfs (without additional reservoir release) in 18 years.

In some years, an objective may be met with base condition flows either before or after it is met with project releases during that same year. Results presented in Table 5-2 account for these occurrences and assume the objective is met in the base condition to prevent double counting in any year. For example, Figure 5-8 shows that releases were sufficient to meet the geomorphic objective in 19 of the 82 years analyzed. However, in one year (1956) the objective was met both under base conditions and then simulated to be met through project release. Results presented in Table 5-2 only show this objective being met during base condition flows to prevent potential double counting.

Figure 5-9 illustrates annual releases from Shasta Reservoir to meet additional agricultural demand in the TCCA service area. Dashed lines show annual unmet contract supply from CalSim II results and green bars illustrate the portion of unmet contract supply satisfied with conjunctive management operations.

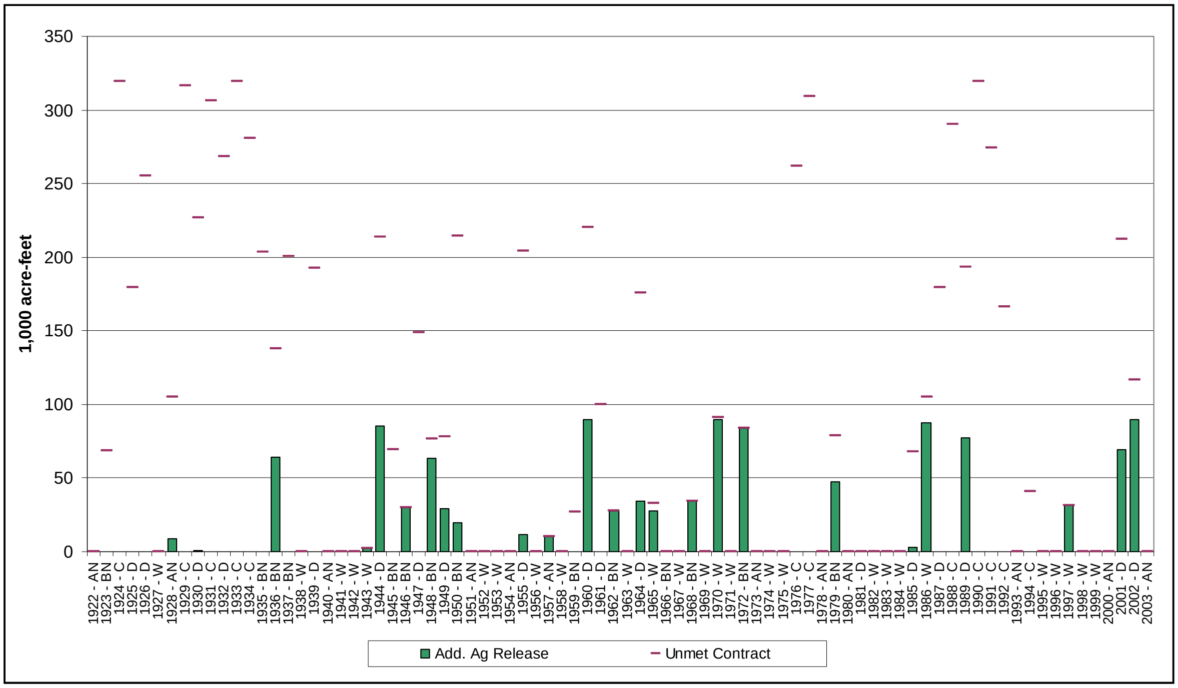

FIGURE 5-9
Sacramento River Additional Agricultural Demand Met with Conjunctive Management, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Additional agricultural releases are made in 24 of the 82 years simulated, or approximately 29 percent of the years. The average release in those years is 46 TAF, while the average annual agricultural delivery over the 82-year simulation period is 14 TAF.

Figure 5-9 illustrates that in many years when unmet contract supply for the TCCA is highest, there are no deliveries with conjunctive use. This is because in these years, project assets are typically low, either because fall reservoir storage is forecast to be low and no additional releases would be made or it is a Shasta Critical year and additional groundwater pumping for conjunctive management is assumed to be zero[14].

Additional reservoir releases for either environmental objectives or for additional agricultural delivery result in lower fall carryover storage in Lake Shasta. Figure 5-7 illustrates this with a probability of exceedance plot for end of September storage conditions. The solid blue line indicates fall storage conditions under base (without project) conditions. The red dashed line indicates conditions with conjunctive management. A solid red line at 2,400 TAF indicates the level when conjunctive management operations would not occur to limit the risk to cold water pool management in future years. Storage conditions below the solid green line at 1,900 TAF are when conjunctive management operations attempt to increase storage by pumping groundwater and holding water in Shasta above base levels[15].

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[14] Curtailment of project pumping in Shasta Critical years was imposed to avoid potential conflicts with the incremental groundwater pumping that typically occurs in those years as Sacramento River settlement contractors attempt to make up for water supply shortages.

[15] The Shasta Reservoir storage levels at which project pumping would be suspended for project purposes or would be invoked for purposes of sustaining Shasta storage are user defined values. Values of 2,400 TAF and 1,900 TAF for these parameters were established through parametric analyses and discussion with CVP operators.

Figure 5-7 illustrates that fall storage levels are lower in approximately 45 percent of the years and only when end of September storage is above 2,400 TAF. In wet years, when fall storage is at the flood control level of 3,400 TAF, releases in spring may refill in later months within the same year resulting in no change in fall storage conditions.

Figure 5-10 illustrates how storage deficits presented on Figure 5-7 are frequently refilled by the capture of surplus surface water. Surplus is water that would otherwise be released from the reservoir to maintain flood control storage and is not diverted downstream. This water is now stored in reservoir space created by making additional releases to meet agricultural and environmental objectives. Refill from surplus surface water occurs in 29 years with an average annual refill of 70 TAF in those years. Average annual refill with surplus surface water for the 82-year simulation is approximately 24 TAF.

In some years, following additional reservoir releases for agricultural and environmental objectives, there is no surplus surface water, and reservoir storage levels continue to decline putting future water supplies and cold water pool management at risk. In these years groundwater pumping in the conjunctive management projects is used to recover reservoir storage levels. Figure 5-11 illustrates this annual pumping. Conjunctive management pumping occurs in 4 of the 82 years simulated, or 5 percent of years. The average annual pumping in those years is 70 TAF. The average annual pumping for the entire 82-year simulation is approximately 3 TAF with a maximum annual pumping of nearly the full 100 TAF of payback capacity. Pumping typically occurs in drier year types when reservoirs do not refill with surplus surface water.

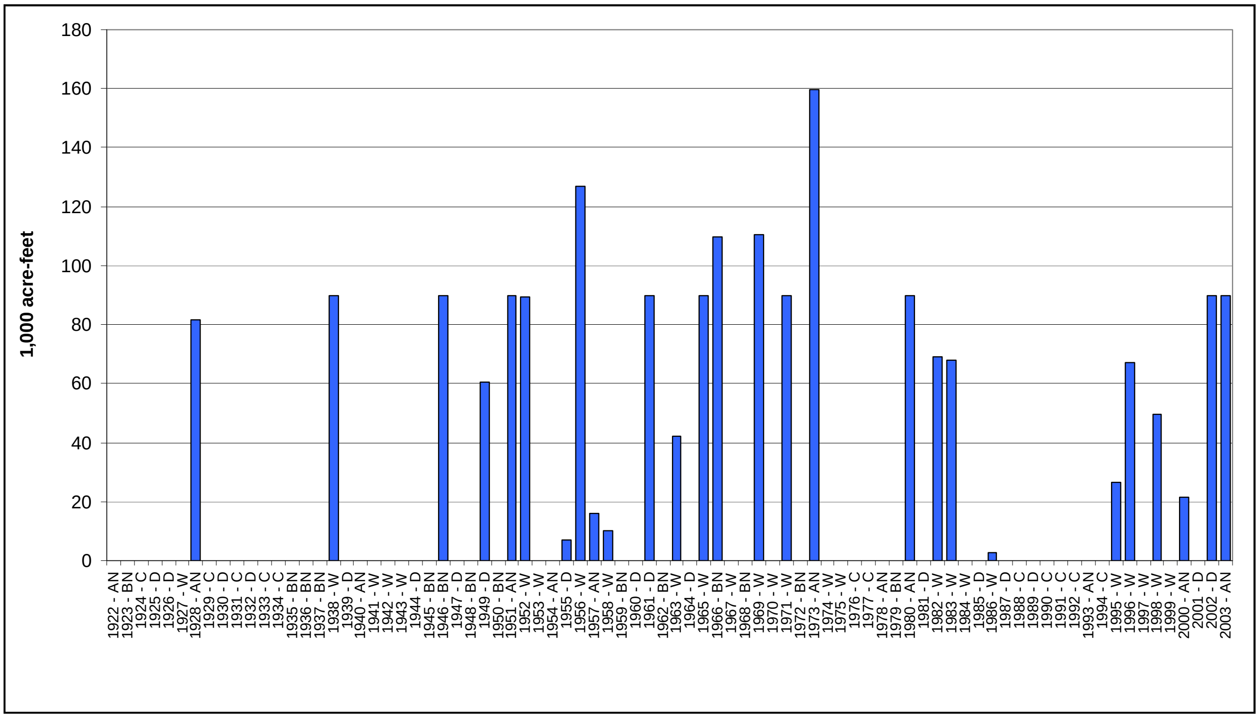

FIGURE 5-10
Refill of Shasta Reservoir from Surplus Surface Water, Scenarios 1, 3 And 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

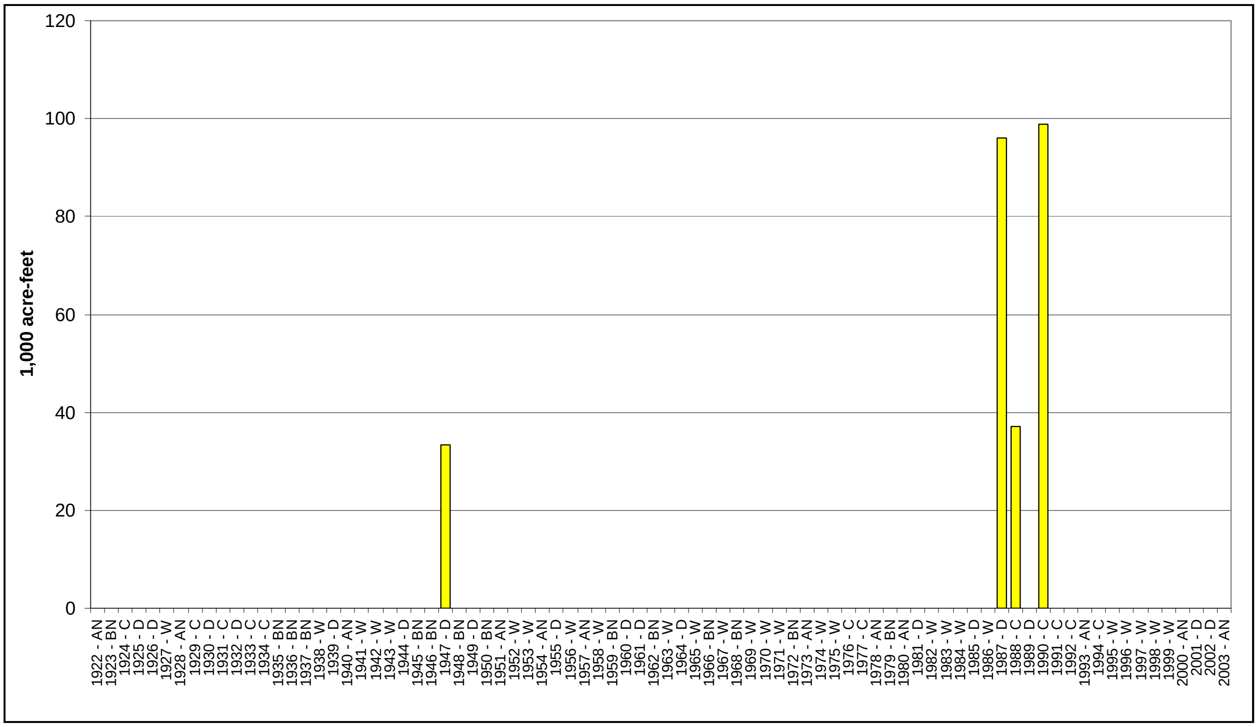

FIGURE 5-11
Refill of Shasta Reservoir from Conjunctive Management Pumping, Scenarios 1, 3 And 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Over the 82-year simulation period, additional reservoir releases are made in 37 years, or 45 percent of the years. Reservoir refill is accomplished with surplus surface flows in 29 years and with project pumping in 4 years. The number of years with additional releases exceeds the number of years with refill because reservoir storage deficits do not have to be completely refilled before making additional releases, as long as the total reservoir storage deficit does not exceed the capacity of the project to refill the reservoir in a single year. Of the total average annual additional releases of 27 TAF (14 TAF for agriculture and 13 TAF for environmental objectives), 24 TAF is refilled from surplus surface water and 3 TAF from conjunctive management pumping. Over the 82-year period of analysis, a total of 1,148 TAF would be delivered to satisfy agricultural demands that would otherwise be met from groundwater pumping. Over the same period, the total volume of project pumping required for reservoir payback would be just 246 TAF. Thus, conjunctive operations would result in a net gain to the groundwater system of more than 900 TAF over the analysis period.

5.3.2. Scenarios 1, 3 and 4 – Oroville Reservoir and Feather River

Figure 5-12 illustrates annual volumes of water released to meet environmental objectives on the Feather River. Hydrology and operations on the Feather River result in meeting different objectives in different years compared to the Sacramento River. Similar to the Sacramento River operations, the geomorphic objective is satisfied most frequently due to lower water cost associated with meeting the shorter duration objective. Average annual release for environmental objectives on the Feather River is 7 TAF.

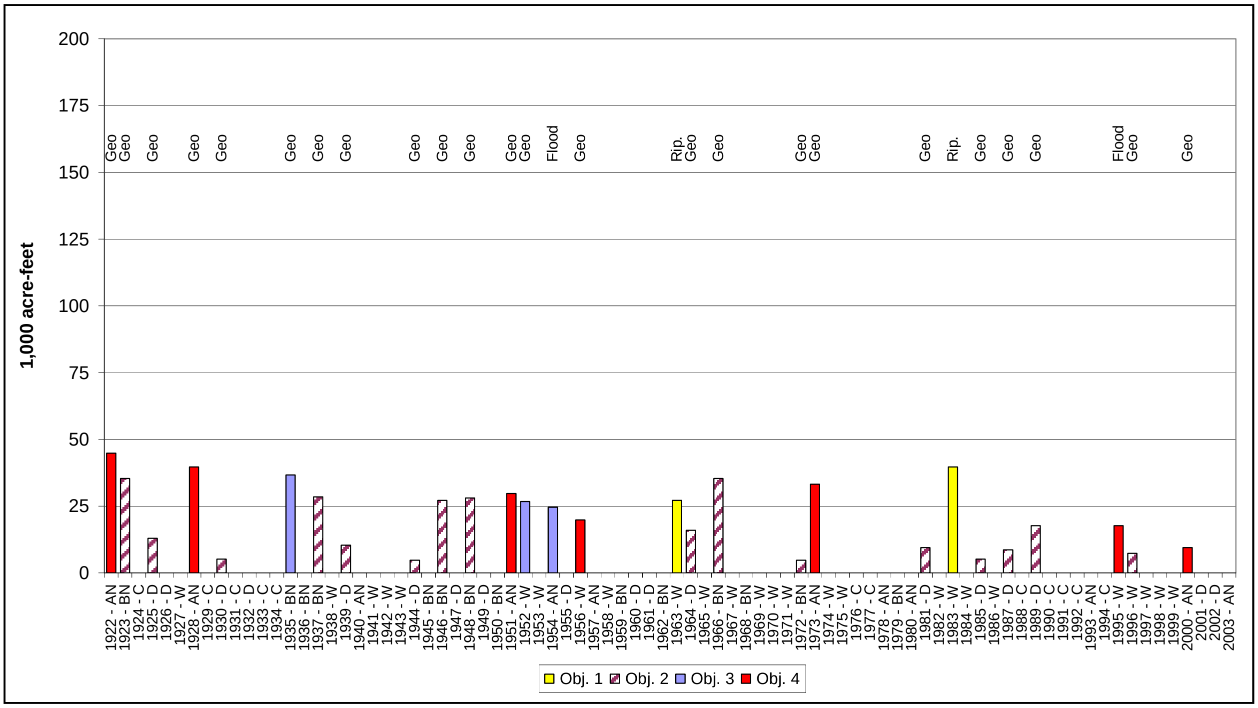

FIGURE 5-12
Feather River Environmental Objectives Met With Conjunctive Management, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Table 5-3 provides a summary of the number of times each objective is met by reservoir release and under base operations on the Feather River. Values reported in the table for the geomorphic objective only include years when the objective is not met under base operations. Therefore this value is less than the number of releases shown on 5-12. The flood plain inundation objective can be met with the project under base condition flows with the modified weir, or with a combination of project releases and the modified weir.

Table 5-3
Number of Years Feather River Environmental Objectives are Met, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Objective	Met in Base	Met with Project	Total
Spring Pulse	3	0	3
Riparian Recruitment	1	2	3
Geomorphic	31	17	48
Flood Plain Inundation	21	20	41

Figure 5-13 illustrates additional agricultural deliveries possible with conjunctive management on the Feather River. Dashed lines relate to assumed unmet demands within the Feather River basin and correspond to the Sacramento Valley Index. Similar to operations on the Sacramento River, project assets do not allow additional releases for either environmental or agricultural objectives during drier year types when agricultural demands are higher. Additional agricultural releases are made in 30 of the 82 years simulated, or approximately 37 percent of the years. The average release in those years is 27 TAF, while the average annual agricultural delivery over the 82-year simulation period is 10 TAF.

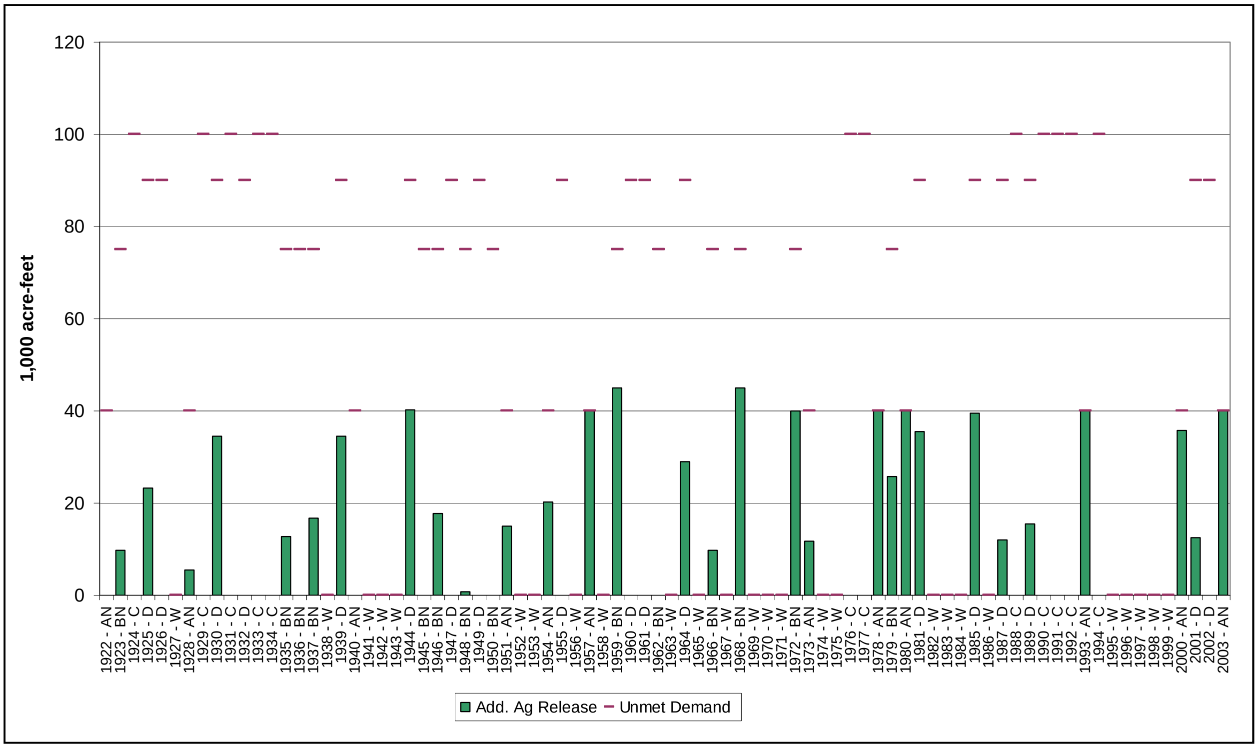

FIGURE 5-13
Feather River Additional Agricultural Demand Met with Conjunctive Management, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Figure 5-14 illustrates how conjunctive management operations result in slightly lower Oroville Reservoir fall storage conditions in approximately 60 percent of the years. Fall storage is not affected below the minimum level of 1,500 TAF. The solid green line at 1,200 TAF denotes target storage for cold water pool management when conjunctive management may be used to increase storage.

Figure 5-15 shows how storage space created in Oroville Reservoir through additional releases for agricultural and environmental objectives is frequently refilled with surplus surface water. Refill from surplus surface water occurs in 37 years with an average annual refill of 32 TAF in those years. The average annual refill with surplus for the 82-year simulation period is 14 TAF.

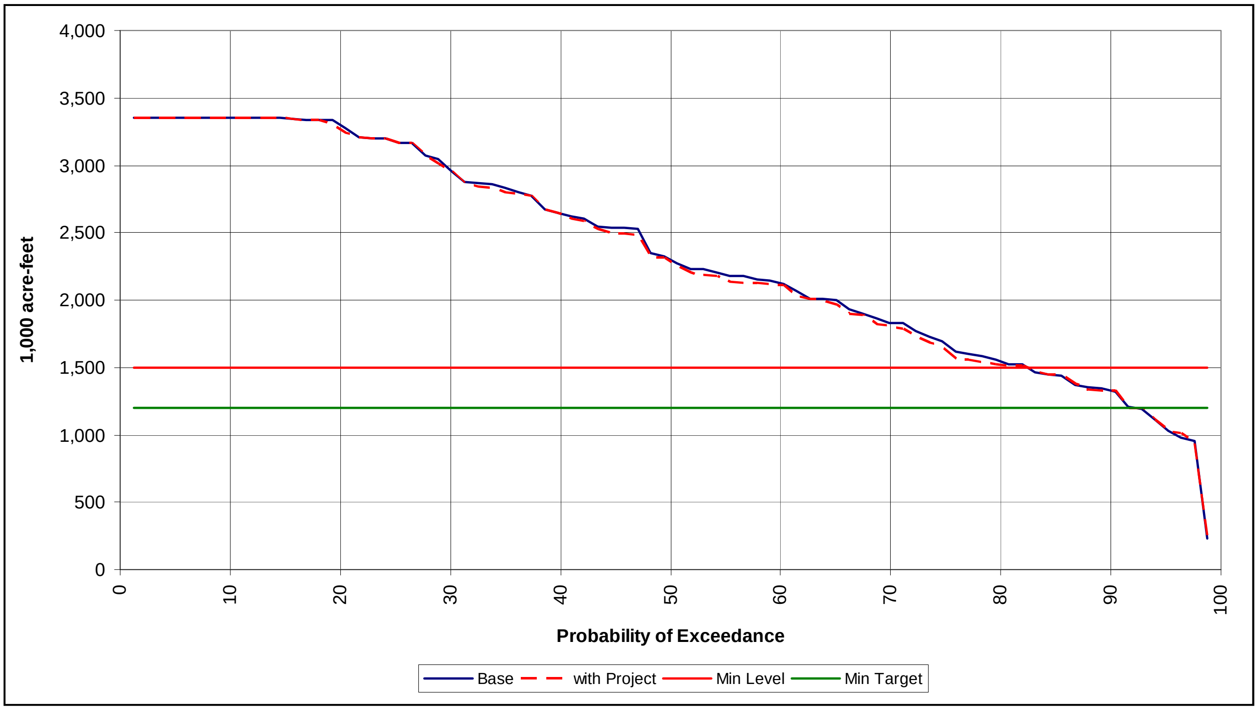

FIGURE 5-14
Oroville Reservoir September Storage Exceedance Probability with Conjunctive Management, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

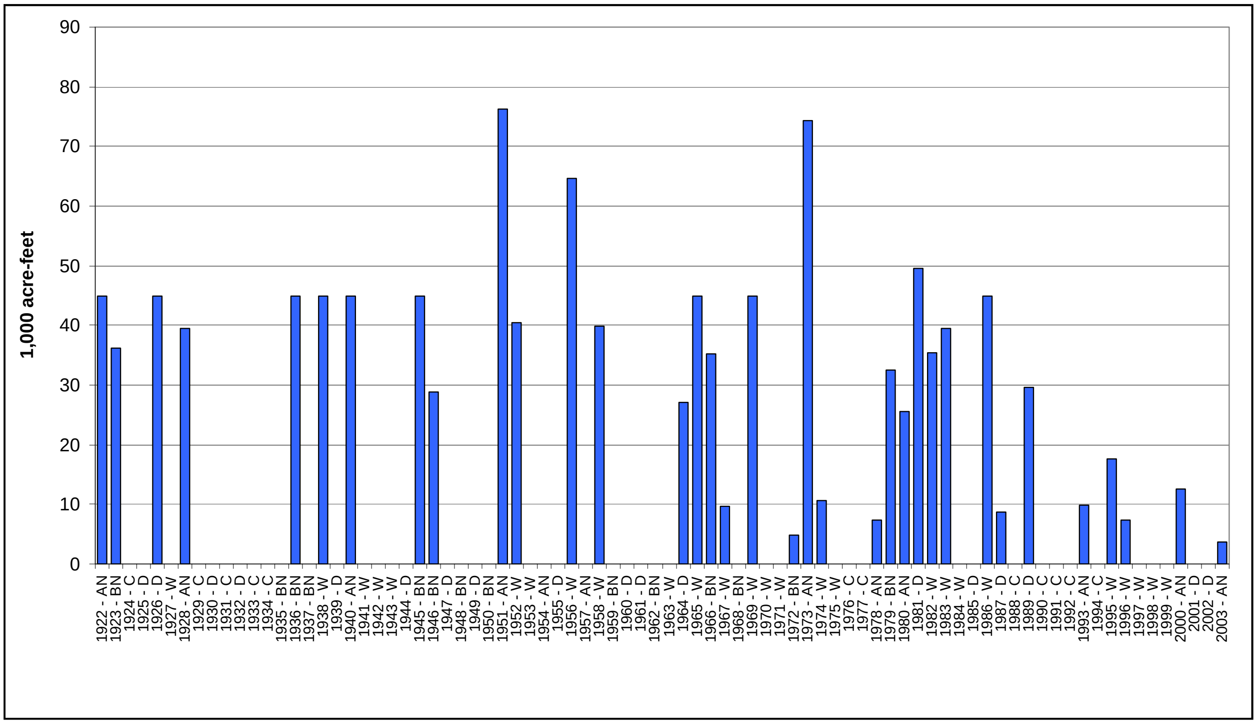

FIGURE 5-15
Refill of Oroville Reservoir from Surplus Surface Water, Scenarios 1, 3 and 4
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Figure 5-16 presents annual conjunctive management pumping in the Butte Basin project. Conjunctive management pumping occurs in 6 of the 82 years simulated or 7 percent of the years. The average annual pumping in those years is 44 TAF. The average annual pumping for the entire 82-year simulation is approximately 3 TAF with a maximum annual pumping of the full 50 TAF of pumping capacity.

Over the 82-year simulation period, additional reservoir releases are made in 37 years, or 45 percent of the years. Reservoir refill is accomplished with surplus surface flows in 37 years and with project pumping in 6 years. The number of years with refill exceeds the number of years with additional release because reservoir storage deficits may not completely refill in a single year, but instead refill over the course of several years. In summary, of total average annual additional releases of 17 TAF (10 TAF for agriculture and 7 TAF for environmental objectives), 14 TAF is refilled from surplus surface water and 3 TAF from conjunctive management pumping. Over the 82-year period of analysis, a total of 820 TAF would be delivered to satisfy agricultural demands that would otherwise be met from groundwater pumping. Over the same period, the total volume of project pumping required for reservoir payback would be just 246 TAF. Thus, conjunctive operations would result in a net gain to the groundwater system of 574 TAF over the analysis period.

5.3.3. Scenario2 – Shasta Reservoir and Sacramento River

Scenario 2 is defined by maximum seasonal pumping capacities of 200 TAF in GCID and 100 TAF in the Butte Basin. This scenario is the same as Scenarios 1, 3 and 4 with respect to environmental and water supply objectives and operating constraints, but with twice the pumping capacity.

Figure 5-17 illustrates annual volumes of water released to satisfy various environmental objectives on the Sacramento River. The geomorphic objective is met most frequently due to lower water cost associated with the short duration, but the larger pumping capacity increases project assets and allows other objectives to be met more frequently than in Scenario 1. Additionally, in some years more than one objective may be met as indicated by stacked bars. Average annual release for environmental objectives under Scenario 2 is 45 TAF.

Figure 5-17 shows only years when environmental objectives are met through project release. Environmental objectives may also be met under the base operations of the system.

Table 5-4 provides a summary of the number of times each objective is met by reservoir release and under base operations on the Sacramento River. Values reported in the table for the geomorphic objective only include those years when the objective is not met under base operations. Therefore this value is less than the number of releases shown on Figure 5-17. The flood plain inundation objective can be met with the project under base condition flows with the modified weir, or with a combination of project releases and the modified weir.

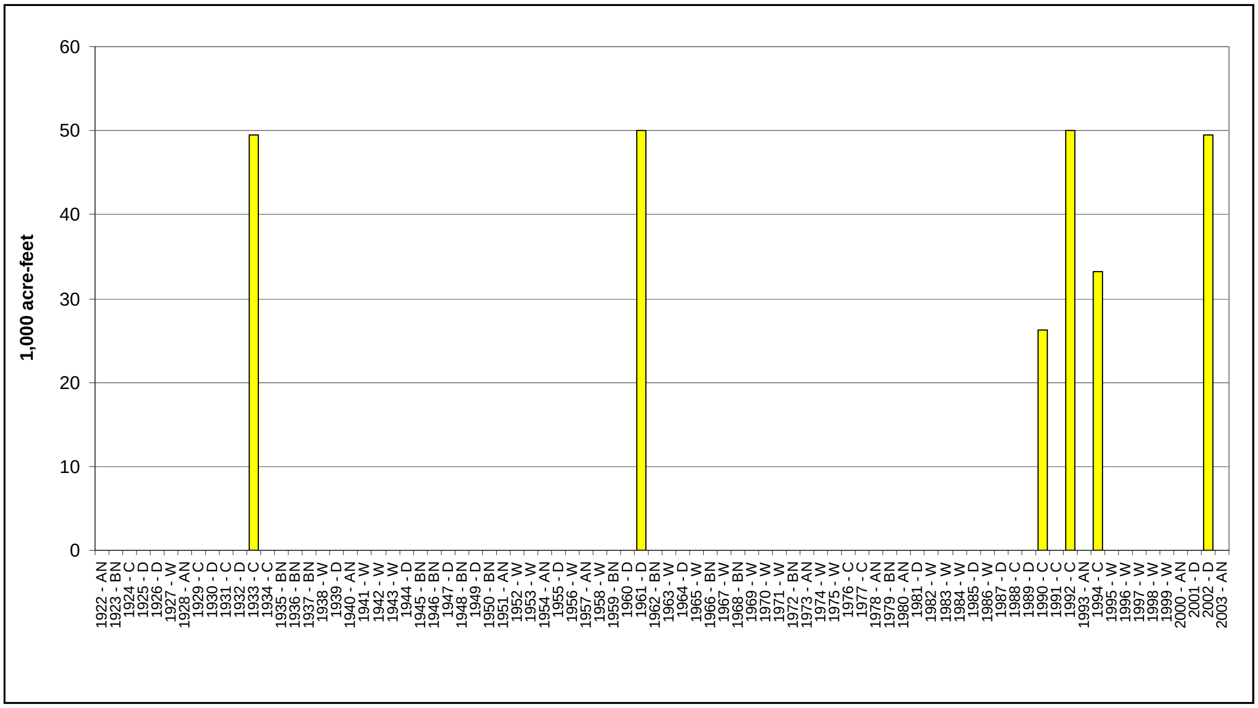

FIGURE 5-16
Refill of Oroville Reservoir from Conjunctive Management Pumping, Scenario 1
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

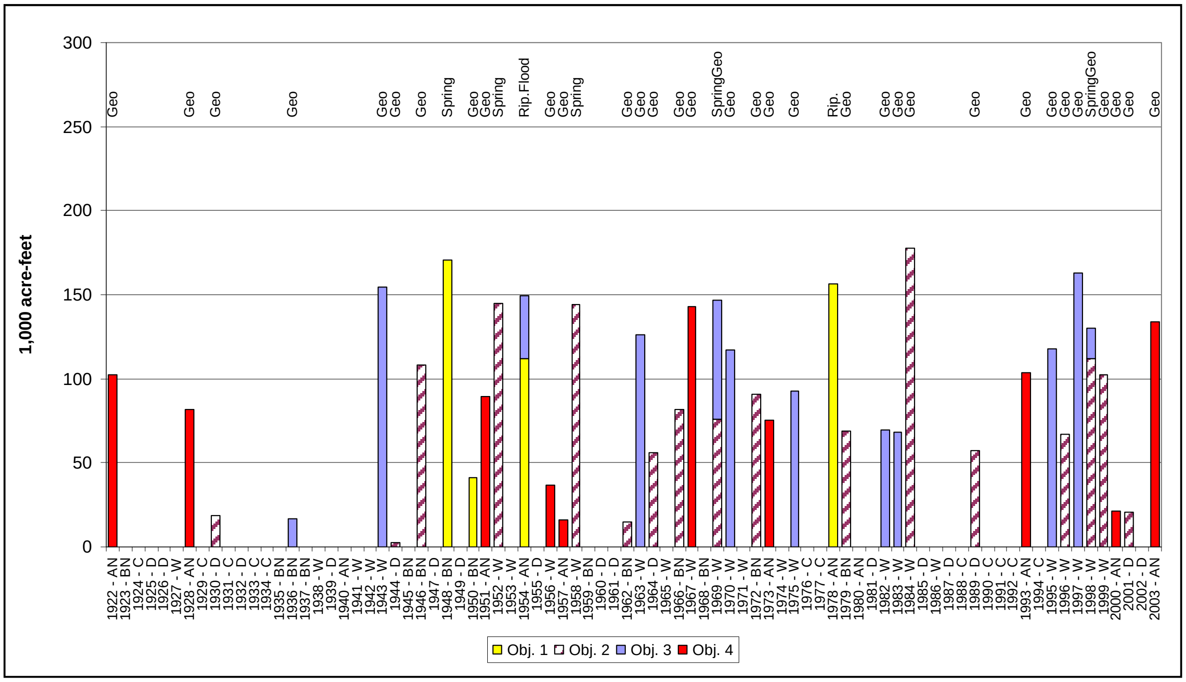

FIGURE 5-17
Sacramento River Environmental Objectives Met With Conjunctive Management, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

TABLE 5-4
Number of Years Sacramento River Environmental Objectives Are Met, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Objective	Met in Base	Met with Project	Total
Spring Pulse	5	5	10
Riparian Recruitment	0	2	2
Geomorphic	25	30	55
Flood Plain Inundation	21	20	41

Figure 5-18 illustrates annual release from Shasta to meet additional agricultural demand in the TCCA service area. Additional agricultural releases are made in 24 of the 82 years simulated, or approximately 29 percent of the years. The average release in those years is 75 TAF, while the average annual agricultural delivery over the 82-year simulation period is 22 TAF. Additional agricultural deliveries are made in many of the same years as in Scenario 1, but at higher volumes.

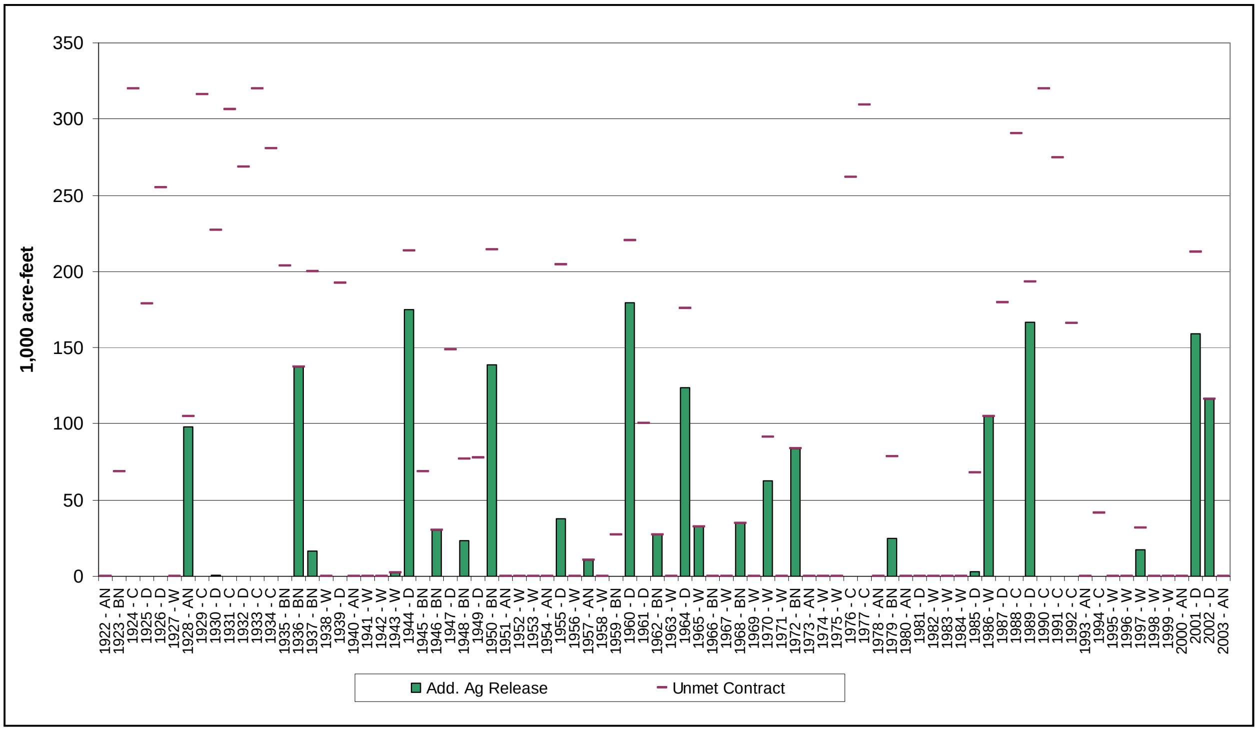

FIGURE 5-18
Sacramento River Additional Agricultural Demand Met With Conjunctive Management, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Additional reservoir releases for either environmental objectives or for additional agricultural delivery result in lower fall carryover storage in Lake Shasta. Figure 5-19 illustrates that fall storage levels are lower in approximately 45 percent of the years and only when end of September storage is more than 2,400 TAF. During these years fall storages are lower compared to Scenario 1 because larger pumping capacity allows for more aggressive operation of the reservoir. Additionally, a small increase in fall storage below the 1,900 TAF target may also be possible.

Figure 5-20 illustrates how storage deficits presented on Figure 5-19 are frequently refilled by capture of surplus surface water. Refill with surplus surface water occurs in 35 years with an average annual refill of 139 TAF in those years. Average annual refill with surplus surface water for the 82-year simulation is approximately 58 TAF.

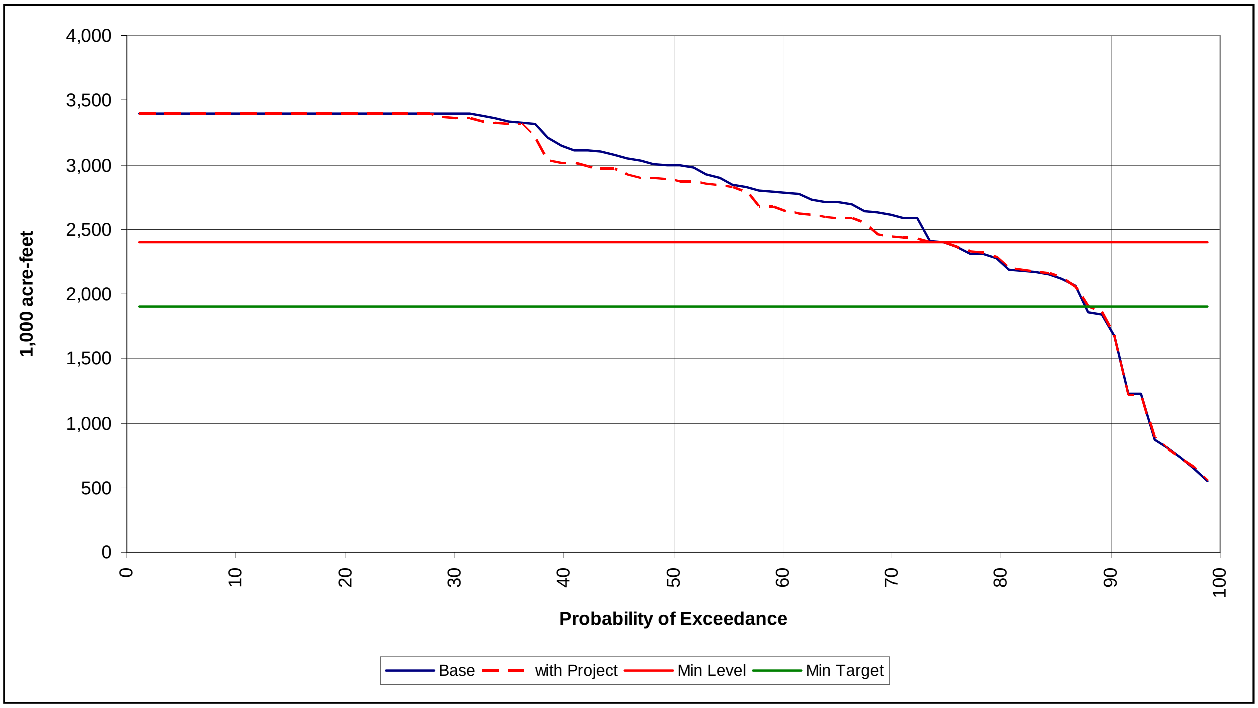

FIGURE 5-19
Shasta Reservoir September Storage Exceedance Probability with Conjunctive Management, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

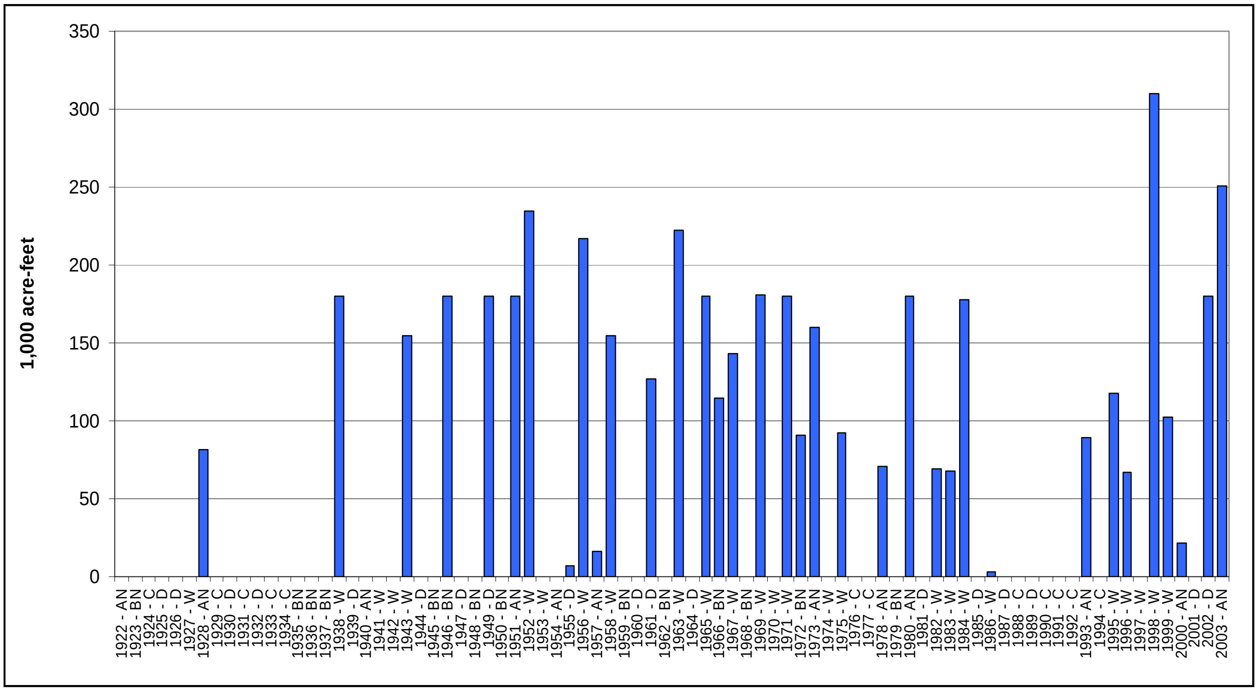

FIGURE 5-20
Refill of Shasta Reservoir from Surplus Surface Water, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Figure 5-21 illustrates annual conjunctive management groundwater pumping for Scenario 2. Conjunctive management pumping occurs in 6 of the 82 years simulated, or 7 percent of years. The average annual pumping in those years is 123 TAF. The average annual pumping for the entire 82-year simulation is approximately 9 TAF with a maximum annual pumping of nearly the full 200 TAF of capacity. Pumping typically occurs in drier year types when reservoirs do not refill with surplus surface water.

Over the 82-year simulation period, additional reservoir releases are made in 48 years, or 59 percent of the years. Reservoir refill is accomplished with surplus surface flows in 35 years and with project pumping in 6 years. The number of years with releases exceeds the number of years with refill because reservoir storage deficits do not have to be completely refilled before making additional releases, as long as the total reservoir storage deficit does not exceed the capacity of the project to refill the reservoir in a single year. In summary, of total average annual additional releases of 67 TAF (22 TAF for agriculture and 45 TAF for environmental objectives), 58 TAF is refilled from surplus surface water and 9 TAF from conjunctive management pumping. Over the 82-year period of analysis, a total of 1,804 TAF would be delivered to satisfy agricultural demands that would otherwise be met from groundwater pumping. Over the same period, the total volume of project pumping required for reservoir payback would be just 738 TAF. Thus, conjunctive operations would result in a net gain to the groundwater system of 1,066 TAF over the analysis period.

5.3.4. Scenario 2 – Oroville Reservoir and Feather River

Figure 5-22 illustrates annual volumes of water released to meet environmental objectives on the Feather River. Similar to the Sacramento River operations, the geomorphic objective is satisfied most frequently, but increased groundwater pumping capacity allows for more aggressive reservoir operations allowing other objectives to also be satisfied. Average annual release for environmental objectives on the Feather River is 23 TAF.

Table 5-5 provides a summary of the number of times each objective is met by reservoir release and under base operations on the Feather River. Values reported in the table for the geomorphic objective only include those years when the objective is not met under base operations. Therefore this value is less than the number of releases shown on Figure 5-22. The flood plain inundation objective can be met with the project under base condition flows with the modified weir, or with a combination of project releases and the modified weir.

Figure 5-23 illustrates additional agricultural deliveries under Scenario 2. Additional agricultural releases are made in 30 of the 82 years simulated, or approximately 37 percent of the years. The average annual release in those years is 52 TAF, while the average annual agricultural delivery over the 82-year simulation period is 20 TAF.

Figure 5-24 illustrates how conjunctive management operations result in lower Oroville fall storage conditions in approximately 60 percent of the years. Fall storage may be increased in a few years when it is below the minimum target level of 1,200 TAF.

Figure 5-25 shows how storage space created in Oroville Reservoir through additional releases for agricultural and environmental objectives is frequently refilled with surplus surface water. This occurs in 43 years with an average annual refill of 72 TAF in those years. Average annual refill with surplus for the 82-year simulation period is approximately 36 TAF.

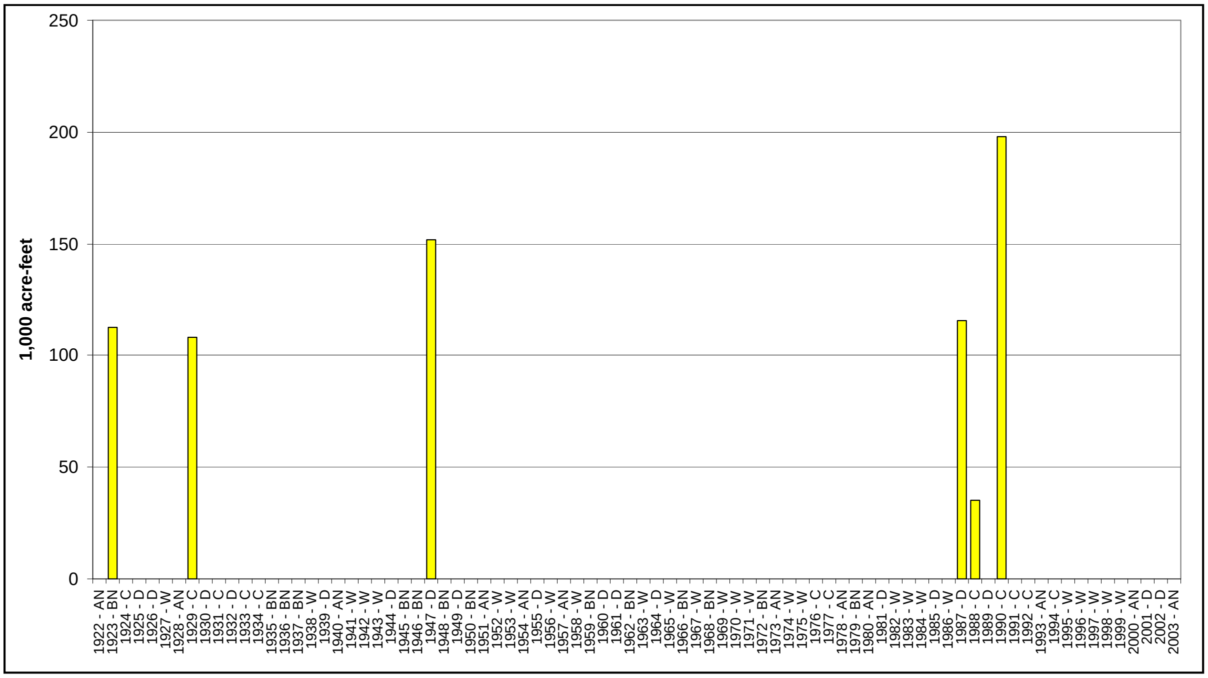

FIGURE 5-21
Refill of Shasta Reservoir from Conjunctive Management Pumping, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

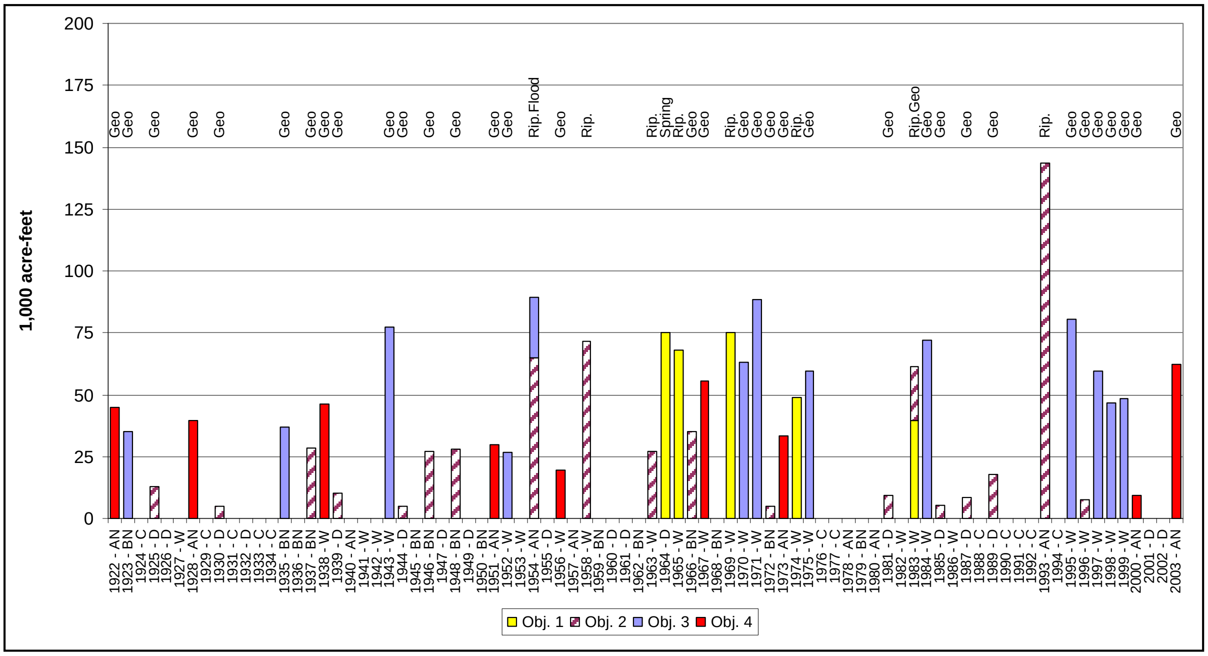

FIGURE 5-22
Feather River Environmental Objectives Met With Conjunctive Management, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

TABLE 5-5
Number of Years Feather River Environmental Objectives are Met, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Objective	Met in Base	Met with Project	Total
Spring Pulse	3	1	4
Riparian Recruitment	1	8	9
Geomorphic	31	25	56
Flood Plain Inundation	21	20	41

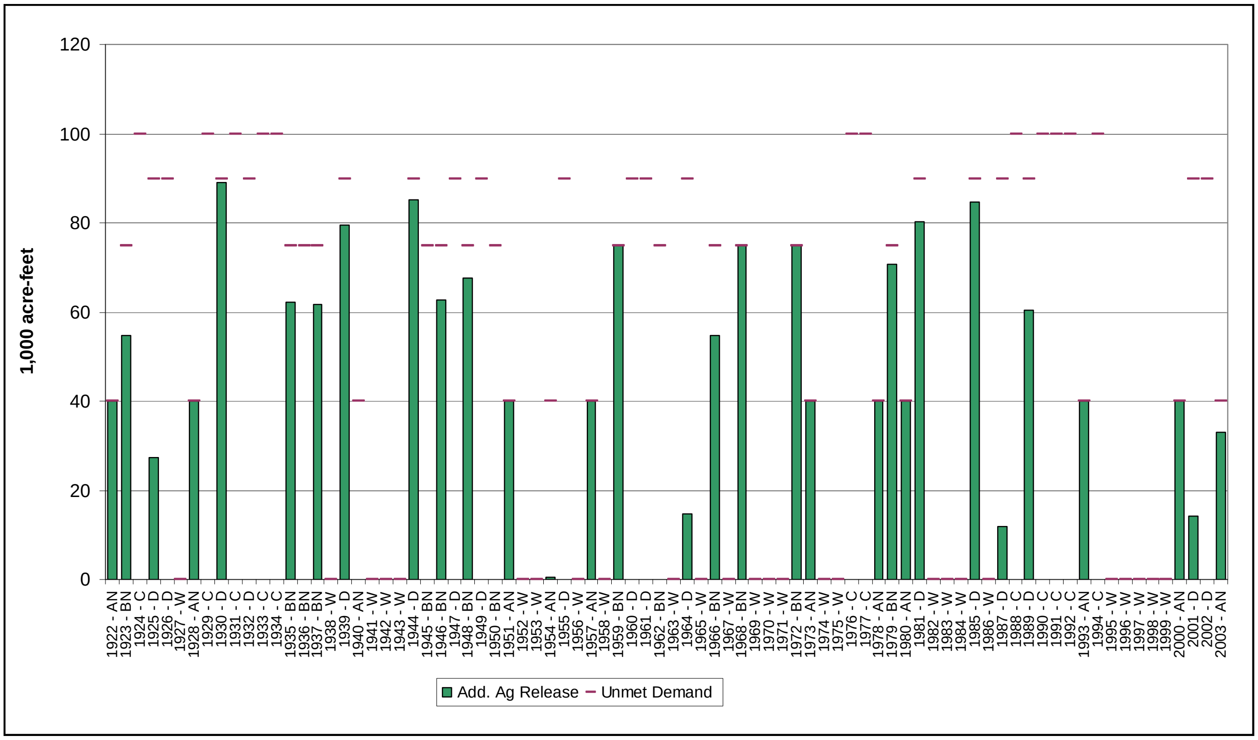

FIGURE 5-23
Feather River Additional Agricultural Demand Met with Conjunctive Management, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

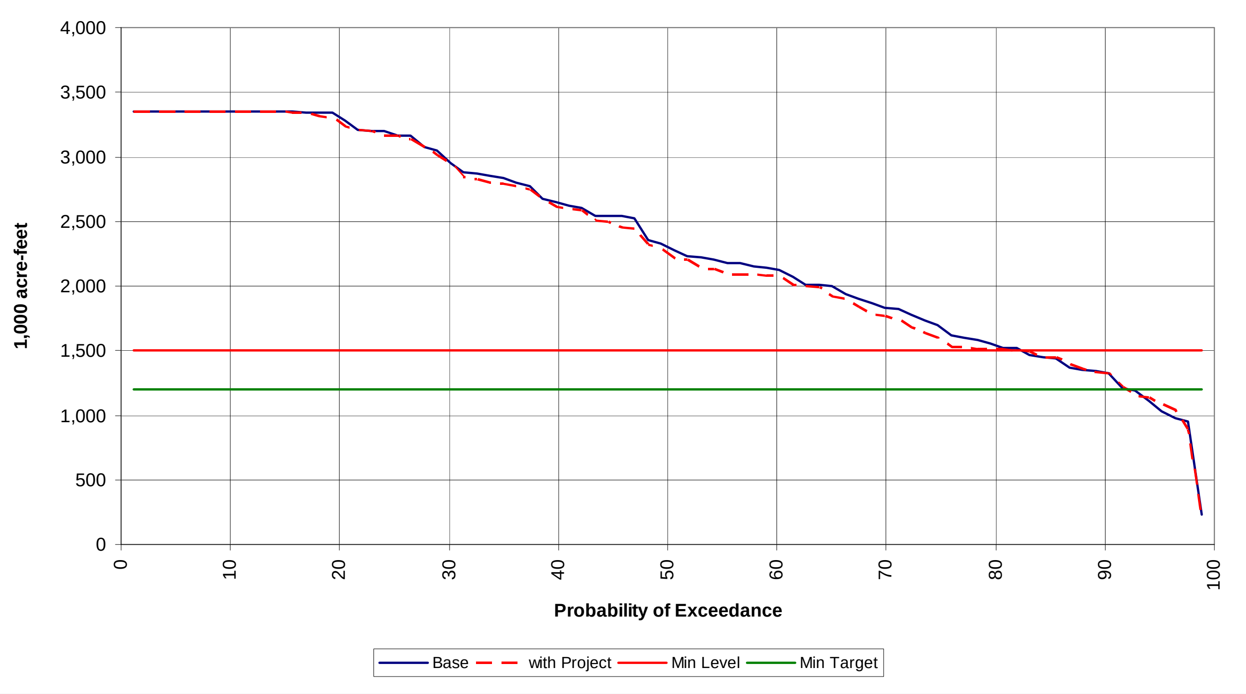

FIGURE 5-24
Oroville Reservoir September Storage Exceedance Probability with Conjunctive Management, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

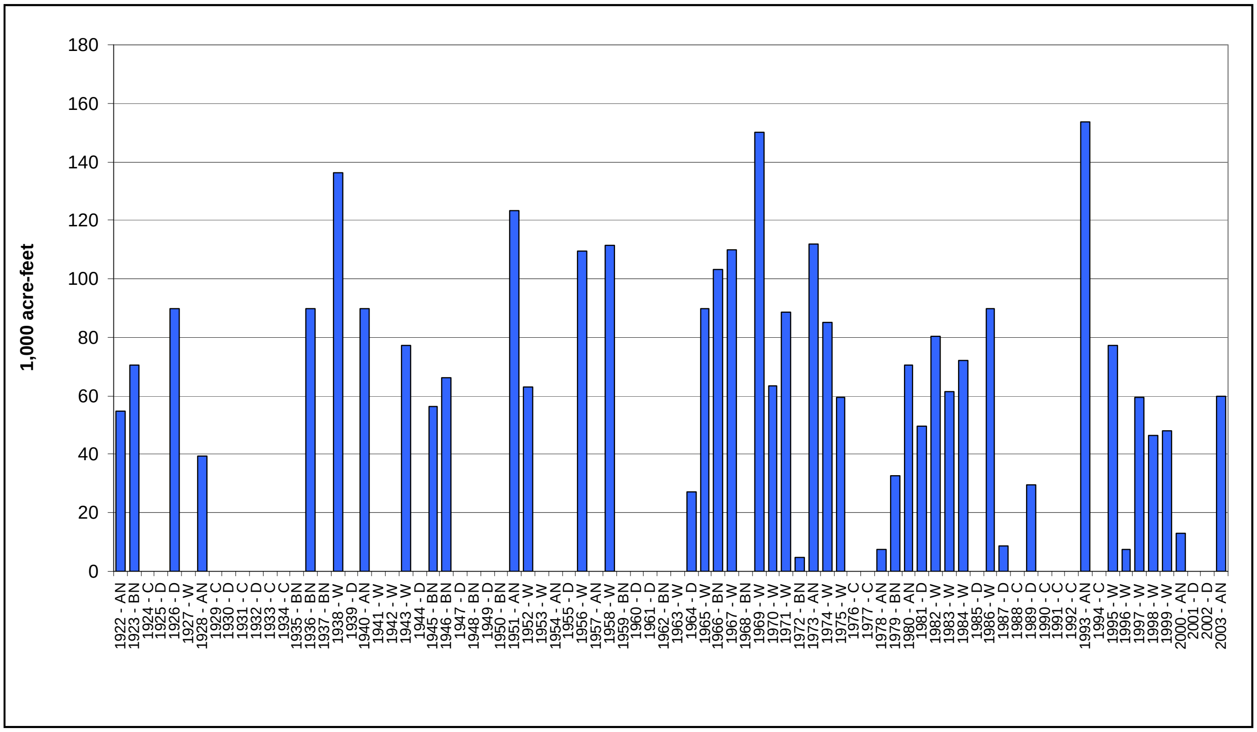

FIGURE 5-25
Refill of Oroville Reservoir from Surplus Surface Water, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Figure 5.26 presents the annual conjunctive management pumping in the Butte Basin project for Scenario 2. Conjunctive management pumping occurs in 8 of the 82 years simulated or 10 percent of the years. The average annual pumping in those years is 75 TAF. The average annual pumping for the entire 82-year simulation is approximately 7 TAF with a maximum annual pumping of the full 100 TAF of pumping capacity.

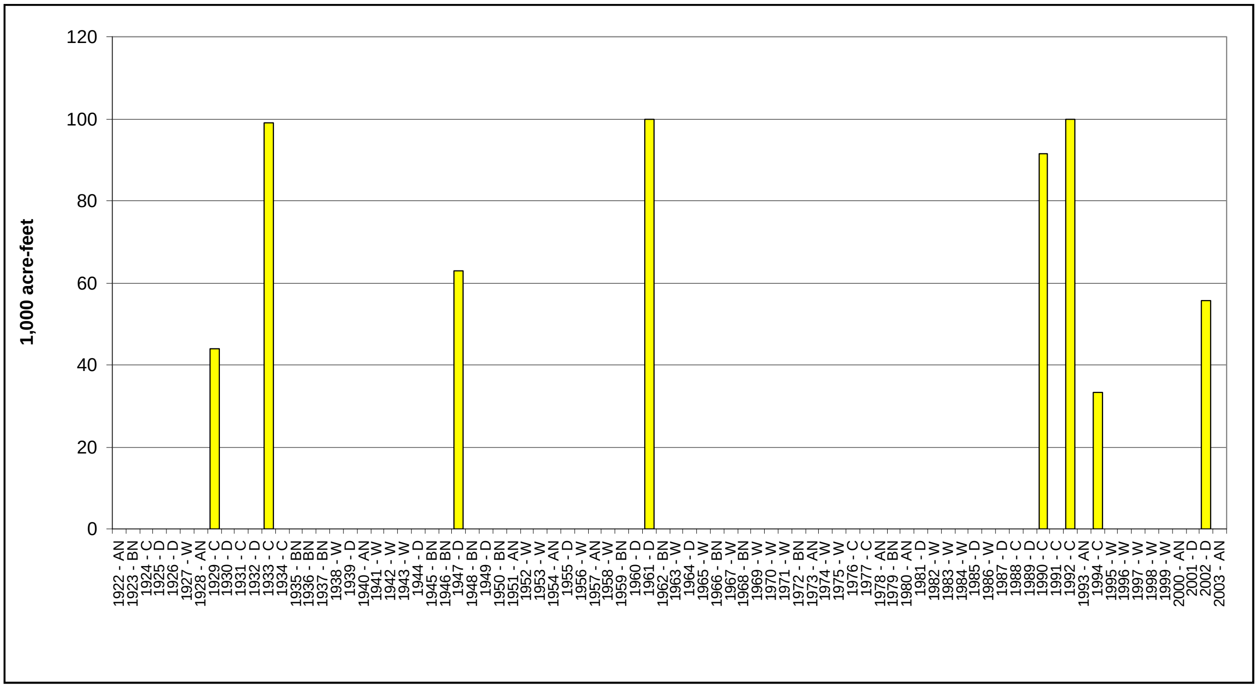

FIGURE 5-26
Refill of Oroville Reservoir from Conjunctive Management Pumping, Scenario 2
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Over the 82-year simulation period, additional reservoir releases are made in 51 years, or 62 percent of the years. Reservoir refill is accomplished with surplus surface flows in 43 years and with project pumping in 8 years. For Scenario 2 on the Feather River system, out of total additional releases of 43 TAF (23 TAF for agriculture and 20 TAF for environmental objectives), 36 TAF is refilled from surplus surface water and 7 TAF from conjunctive management pumping. Over the 82-year period of analysis, a total of 1,886 TAF would be delivered to satisfy agricultural demands that would otherwise be met from groundwater pumping. Over the same period, the total volume of project pumping required for reservoir payback would be just 574 TAF. Thus, conjunctive operations would result in a net gain to the groundwater system of 1,312 TAF over the analysis period.

5.4.Impacts and Evaluation of Initial Scenarios

In the preceding section the initial project scenarios are described with respect to their performance; that is, the ability to achieve targeted project objectives (environmental flows and agricultural water supplies) subject to identified constraints. In this section, the scenarios are described in terms of how project pumping would affect groundwater conditions with particular emphasis on impacts to existing groundwater users, groundwater pumping costs and streamflows.

5.4.1. Impacts on Groundwater Users

During average rainfall years, groundwater supplies 18 percent of the total demand for the Sacramento River Basin, and during drought years groundwater supplies 25 percent of total demand.[16] Wells in the Project area primarily provide groundwater directly to homes and farms. A few municipal water supply agencies also utilize groundwater on the fringes of the Project area, including Chico and Durham.

The great majority of wells in the area are associated with domestic use, with groundwater supplying water to essentially all households. Conversely, surface water is the primary source of irrigation supply for the majority of the farmers. Most of these are incorporated into water or irrigation districts, the largest of which are the partners in this Project, Glenn-Colusa Irrigation District, Western Canal Water District, and Richvale Irrigation District, and various smaller reclamation and irrigation districts and water user associations. However, for those agricultural users outside these districts, many of which are orchardists, groundwater is the main source of supply. It is the domestic well users and farmers growing permanent crops that are most vulnerable to increases in groundwater extractions.

Based on well log data maintained by the Department of Water Resources, there are approximately 15,000 water supply wells (in contrast to monitoring wells) within the Project area, of which approximately two thirds are domestic wells and one third are irrigation wells (Table 5-6). Municipal and irrigation wells are typically screened at lower levels than domestic wells, yet there is a wide range of depths for all types of wells. Approximately 335 wells in the Sacramento Valley extract water from the Lower Tuscan Formation, and these tend to be larger irrigation or public water supply wells. Most of these are located on the east side of the Valley in Butte County, while several agricultural wells on west side of the Valley in GCID and other districts also tap into the Lower Tuscan aquifer.[17]

TABLE 5-6
Number of Water Supply Wells in Project Area[18]
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Use	Number of wells
Domestic	9,058
Irrigation	4,455
Unknown[19]	1,388
Other[4]	267
Municipal	139
Stock	75
Public	52
Total	15,434

Agriculture is the major industry throughout the Project area. Primary crops consist of rice and orchards (almonds, grapes, walnuts). The proportion of agricultural land planted as orchards is increasing as the

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[16] Domagalski, J.L., Knifong, D.L., Dileanis, P.D., Brown, L.R., May, J.T., Connor, Valerie, and Alpers, C.N. 2000. Water Quality in the Sacramento River Basin, California, 1994–98: U.S. Geological Survey Circular 1215. Available on-line at http://pubs.water.usgs.gov/circ1215/.

[17] Northern California Water Users Association. 2005. Sacramento Valley Groundwater: An approach to better understand and manage the Lower Tuscan groundwater resources for northern California. Available at: http://www.norcalwater.org/pdf/sacramento_valley_groundwater_0919.pdf.

[18] Data provided by California Department of Water Resources Northern District Office. 2009.

[19] May include monitoring wells, vapor recovery wells, or other wells not constructed for water supply purposes.

area transitions from row crops to perennial crops and from low-value agronomic crops to higher value vegetable or other row crops. Many individual growers' livelihoods are dependent on having an adequate and affordable supply of groundwater to meet crop water requirements at all times. Of these users, growers of perennial crops and particularly orchardists are often solely dependent on groundwater and are especially vulnerable to even temporary decreases in supply.

5.4.1.1. Occurrence of Project Pumping and Potential Impacts

The Project pumping scenarios designate an annual maximum volume of water that can be released from existing reservoirs to meet local irrigation demands and environmental flow targets. As noted above, in most years, the reservoir space created by additional Project releases is naturally refilled with surplus surface water, which dam operators would otherwise release for flood control. However, in years when refill is less than would have otherwise occurred, pumping of groundwater in lieu of diverting surface water is implemented to make up the difference. This allows a volume of water equivalent to the foregone diversions to remain in reservoir storage.

The surface model predicted the need for pumping in about 10 percent of the years in the Butte Basin and about 7 percent of the years in GCID under the 300 TAF pumping scenarios (see Table 5-7). In years in which pumping occurs, pumping is usually required in either GCID or in the Butte Basin, but not both. However, in exceptionally dry years, pumping would occur in both areas in the same year.

TABLE 5-7
Occurrence of Pumping
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Maximum Pumping	Number of times pumping occurs (82 years of record)		Years in which pumping occurs		Number of times pumping occurs in GCID and/or Butte Basin
	GCID - Shasta	Butte - Oroville	GCID - Shasta	Butte - Oroville	
150 TAF (100 TAF GCID; 50 TAF Butte Basin)	4	6	1947, 1987, 1988, 1990	1933, 1961, **1990**, 1992, 1994, 2002	9
300 TAF (200 TAF GCID;100 TAF Butte Basin)	6	8	1923, **1929**, **1947**, 1987, 1988, **1990**	**1929**, 1933, **1947**, 1961, **1990**, 1992, 1994, 2002	11

* **bolded** years indicate that pumping would have occurred in both GCID and Butte Basin under the Project.

The groundwater model results reveal that the project pumping scenarios will result in increased energy requirements and associated costs to maintain existing pumping volumes.[20] However, at the scale of feasible operations under the Keswick minimum release constraint, the additional drawdown is not expected to reduce the yield of either agricultural or domestic wells. This is particularly clear for the irrigation wells because the screened interval (which provides a bases for estimating minimum saturated thickness under pumping conditions) and well depth tend to be much greater than peak interference drawdown associated with the payback pumping.

The numbers of wells experiencing reduced yield due to interference drawdown were estimated for individual domestic wells within the Project area based on comparison of the length of the screened

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[20] Well yield impacts and increases in energy costs associated with increased lift were assessed using a combination of data provided by DWR describing screened interval lengths within the Project area in conjunction with interference drawdown estimated using the groundwater model.

interval to peak interference drawdown. Because screened interval length data were not available for all wells, results for wells with available data were scaled upwards to provide estimates of the total probable range of wells impacted.

Individual domestic wells were considered to be adversely impacted under the following conditions:

1. When the amount of peak interference drawdown from project pumping results in less than 25 percent of the total screened interval remains saturated, assuming that 50 percent of the screened interval would remain saturated under baseline pumping drawdown,. This criterion was established to provide an estimate of the maximum probable number of wells impacted.

2. When the amount of peak interference drawdown from project pumping results in less than 33 percent of the remaining screened interval (17% of the total) remaining saturated, assuming that 50 percent of the screened interval remains saturated under baseline pumping drawdown. This criterion was established to provide an estimate of the minimum probable number of wells impacted.

A summary of the estimated probable range of wells impacted within potential impact zones, delineated as areas experiencing peak interference drawdown greater than or equal to 2 feet, is provided in Table 5-8. A summary of average monthly interference drawdown within the Project area calculated at the section scale over the 17 year analysis period for each scenario is provided in Table 5-9. In general, the pumping of new wells, screened at 900 to 1100 feet below ground surface (ft-bgs), results in less yield impacts than the equivalent volume of water pumped on the same schedule from existing domestic wells screened at 0 to 300 ft-bgs. This is the case notwithstanding that production from new wells results in greater drawdown in the shallow aquifer, on average, than pumping the same quantities at the same rates from existing wells. This is explained by the hypothesis that greater yield impacts occur with less interference drawdown for the pumping scenarios relying on existing wells because existing production wells are closer to existing domestic wells than the new well field. Also, for a given project production capacity and well field, the greatest peak drawdown is observed in fall pumping simulations because pumping is concentrated within three months as compared to four months for the summer pumping scenarios and seven months for the summer and fall pumping scenarios. As expected, an intermediate magnitude of drawdown is observed for pumping over the four month summer period, and the least drawdown is predicted for the seven month summer and fall pumping period.

5.4.1.2. Timing of Peak Interference Drawdown and Associated Impacts

Under each of the pumping scenarios, peak interference drawdown occurs for most domestic wells in 1990, when Project pumping occurred in both GCID and the Butte Basin. Additionally, in the simulations, the largest volume of water was pumped out of GCID in 1990, and the largest total volume of water was pumped for the Project as a whole in that year (Table 5-10). Thus, 1990 represents a “worst-case scenario” for the period of record.

Within the potential impact area for yield impacts (interference drawdown of 2 feet or more) for each pumping scenario, the maximum number of domestic wells experiencing peak drawdown occurs in 1990. Peak drawdown at a well lags project pumping by a few months due to the time required for pumping in the lower aquifer to result in drawdown in the shallow aquifer. The time series of project pumping and domestic wells experiencing peak drawdown is shown for the 300 TAF summer pumping scenarios in Figure 5-27.

TABLE 5-8
Estimated Probable Range of Domestic Well Yield Impacts
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

		Minimum Probable Impacts[2]		Maximum Probable Impacts[3]	
Pumping Scenario	Total Wells[1]	Percent Impacted[4]	Total Impacted[5]	Percent Impacted[4]	Total Impacted[5]
300 TAF, Summer Pumping, New Well Field	756	8%	58	21%	158
300 TAF, Summer Pumping, Existing Well Field	696	22%	153	41%	284
150 TAF, Summer Pumping, New Well Field	120	5%	6	23%	27
150 TAF, Summer Pumping, Existing Well Field	346	26%	91	50%	173
150 TAF, Fall Pumping, New Well Field	182	3%	6	16%	29
150 TAF, Fall Pumping, Existing Well Field	405	21%	84	44%	180
150 TAF, Summer and Fall Pumping, New Well Field	156	5%	8	16%	25
150 TAF, Summer and Fall Pumping, Existing Well Field	373	17%	63	35%	130

1. Total domestic wells within potential impact zones (maximum interference drawdown greater than or equal to 2 feet).
2. Estimated impacts based on peak interference drawdown greater than 67% of estimated saturated screened interval.
3. Estimated impacts based on peak interference drawdown greater than 50% of estimated saturated screened interval.
4. Percent of wells within potential impact zones with yield impacts.
5. Estimated total number of wells within potential impact zones with yield impacts.

TABLE 5-9
Summary Statistics of Monthly Average Interference Drawdown in the Shallow Aquifer by Pumping Scenario, 1987 – 2003
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Interference Drawdown (ft)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	0.0	13.6	0.5	0.3	0.7
300 TAF Summer Pumping, Existing Well Field	0.0	8.3	0.4	0.2	0.6
150 TAF Summer Pumping, New Well Field	0.0	6.2	0.3	0.2	0.4
150 TAF Summer Pumping, Existing Well Field	0.0	5.4	0.3	0.2	0.4
150 TAF Fall Pumping, New Well Field	0.0	7.0	0.4	0.2	0.4
150 TAF Fall Pumping, Existing Well Field	0.0	6.1	0.4	0.2	0.5
150 TAF Summer & Fall Pumping, New Well Field	0.0	5.9	0.4	0.2	0.4
150 TAF Summer & Fall Pumping, Existing Well Field	0.0	5.0	0.4	0.2	0.5

TABLE 5-10
Volume of Water Pumped by Year, Scenario, and Area
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Calendar Year	Pumping Scenario											
	300 TAF Summer			150 TAF Summer			150 TAF Fall			150 TAF Summer and Fall		
	GCID	Butte	TOTAL	GCID	Butte	TOTAL	GCID	Butte	TOTAL	GCID	Butte	TOTAL
1987	116	0	116	96	0	96	96	0	96	95	0	95
1988	35	0	35	37	0	37	60	0	60	53	0	53
1990	198	92	289	99	26	125	99	50	149	97	41	138
1992	0	100	100	0	50	50	0	50	50	0	50	50
1994	0	33	33	0	33	33	0	50	50	0	48	48
2002	0	56	56	0	49	49	0	49	49	0	48	48
TOTAL	349	280	629	232	159	391	255	199	454	245	188	432

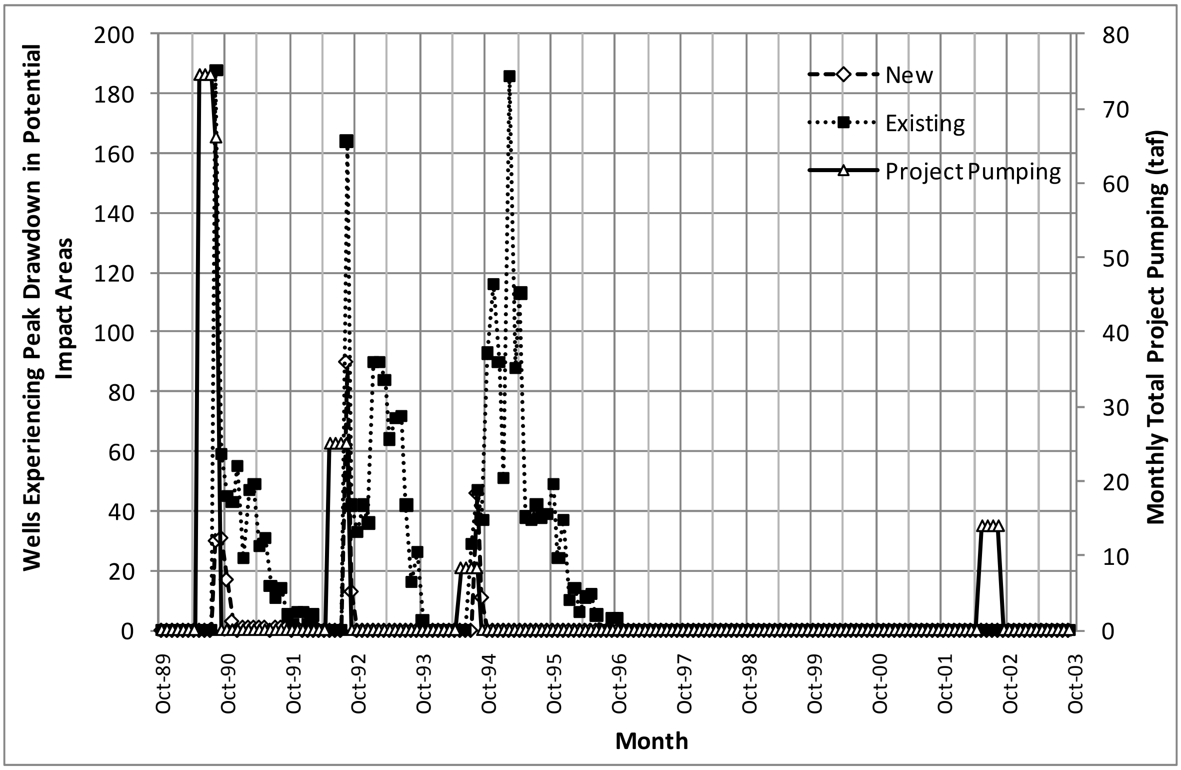

FIGURE 5-27
Project Pumping for 300 TAF Summer Pumping Scenarios and Number of Domestic Wells Experiencing Peak Interference Drawdown
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

5.4.1.3. Increase in Pumping Energy Costs

Project pumping will result in amounts of drawdown that will not be great enough to adversely impact yield in nearby wells in most cases; however, the drawdown will require all groundwater users (agricultural and domestic) to lift water from slightly greater depths, resulting in additional pumping costs. Additional pumping costs associated with increased lift were estimated for irrigation wells based on baseline groundwater pumping from the surface water model, interference drawdown from the groundwater model, estimated mean overall pumping plant efficiency for irrigation wells, and the estimated agricultural energy cost per kilowatt-hour. For domestic wells, additional pumping costs were estimated based on baseline pumping estimated from the combination of spatially distributed U.S. Census data for 2000 and per-capita non-irrigation groundwater pumping for 2005 from USGS, interference drawdown from the groundwater model, estimated mean overall pumping plant efficiency for domestic wells, and the estimated residential energy cost per kilowatt-hour. Increased energy requirements and associated costs were estimated for individual sections within the Project area on a monthly time step for water years 1987 to 2003.

Baseline pumping and interference drawdown vary with time and location within the project area. As a result, associated increases in pumping costs vary. Summary statistics of increased annual energy requirements per acre to maintain existing levels of groundwater pumping for irrigation are provided for each pumping scenario in Table 5-11. Summary statistics of increased annual energy requirements per acre to maintain existing irrigation pumping are provided in Table 5-12. The summary statistics describe the increased energy requirements for 1589 of 1786 sections within the Project area that pump groundwater for irrigation based on the results of the surface water model. Summary statistics of total annual increases to energy costs within the Project area for the 17 years of analysis are provided in Table 5-13.

Increases in energy requirements and associated costs are greatest for the 300,000 ac-ft pumping scenarios due to greater interference drawdown resulting from greater Project pumping volumes.

TABLE 5-11
Summary Statistics of Increased Annual Energy Requirements Per Acre to Maintain Existing Groundwater Pumping for Irrigation
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Increased Annual Energy Requirement (kwh/ac)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	0.00	55.6	1.60	0.63	2.80
300 TAF Summer Pumping, Existing Well Field	0.00	46.9	1.36	0.48	2.61
150 TAF Summer Pumping, New Well Field	0.00	27.8	0.97	0.41	1.63
150 TAF Summer Pumping, Existing Well Field	0.00	42.5	1.03	0.39	1.85
150 TAF Fall Pumping, New Well Field	0.00	21.0	0.86	0.38	1.39
150 TAF Fall Pumping, Existing Well Field	0.00	28.0	0.97	0.38	1.65
150 TAF Summer & Fall Pumping, New Well Field	0.00	19.4	0.98	0.44	1.53
150 TAF Summer & Fall Pumping, Existing Well Field	0.00	30.2	1.06	0.42	1.76

TABLE 5-12
Summary Statistics of Increased Annual Energy Costs Per Acre to Maintain Existing Groundwater Pumping for Irrigation
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Increased Annual Energy Cost ($/ac)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	$ -	$ 12.23	$ 0.35	$ 0.14	$ 0.62
300 TAF Summer Pumping, Existing Well Field	$ -	$ 10.31	$ 0.30	$ 0.11	$ 0.58
150 TAF Summer Pumping, New Well Field	$ -	$ 6.11	$ 0.21	$ 0.09	$ 0.36
150 TAF Summer Pumping, Existing Well Field	$ -	$ 9.35	$ 0.23	$ 0.09	$ 0.41
150 TAF Fall Pumping, New Well Field	$ -	$ 4.62	$ 0.19	$ 0.08	$ 0.30
150 TAF Fall Pumping, Existing Well Field	$ -	$ 6.16	$ 0.21	$ 0.08	$ 0.36
150 TAF Summer & Fall Pumping, New Well Field	$ -	$ 4.28	$ 0.22	$ 0.10	$ 0.34
150 TAF Summer & Fall Pumping, Existing Well Field	$ -	$ 6.63	$ 0.23	$ 0.09	$ 0.39

TABLE 5-13
Summary Statistics of Total Increased Annual Energy Costs to Maintain Existing Groundwater Pumping for Irrigation
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Increased Annual Energy Cost (Total $)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	$65,770	$705,326	$228,397	$168,480	$177,411
300 TAF Summer Pumping, Existing Well Field	$60,110	$497,233	$194,859	$154,452	$140,481
150 TAF Summer Pumping, New Well Field	$37,538	$377,222	$139,402	$104,710	$ 94,209
150 TAF Summer Pumping, Existing Well Field	$39,866	$367,467	$148,075	$126,209	$ 97,078
150 TAF Fall Pumping, New Well Field	$10,993	$344,156	$122,601	$124,133	$ 80,913
150 TAF Fall Pumping, Existing Well Field	$10,292	$401,570	$138,222	$134,018	$ 95,827
150 TAF Summer & Fall Pumping, New Well Field	$44,736	$294,296	$140,169	$120,727	$ 81,830
150 TAF Summer & Fall Pumping, Existing Well Field	$47,471	$345,330	$151,533	$132,451	$ 91,202

Increases in energy requirements are least for the fall pumping scenarios due to the lesser volume of Project pumping (as compared to the 300 TAF summer pumping scenarios) and due to Project pumping occurring after the peak irrigation season, when baseline irrigation pumping is less. Costs tend to be similar whether Project pumping relies on a new or existing well field.

Annual baseline irrigation pumping, Project pumping, and increased energy costs by water year are shown for the 300 TAF summer pumping scenario with a new well field in Figure 5-28. Annual baseline irrigation pumping, Project pumping, and increased energy costs by water year are shown for the 300 TAF summer pumping scenario with an existing well field in Figure 5-29.

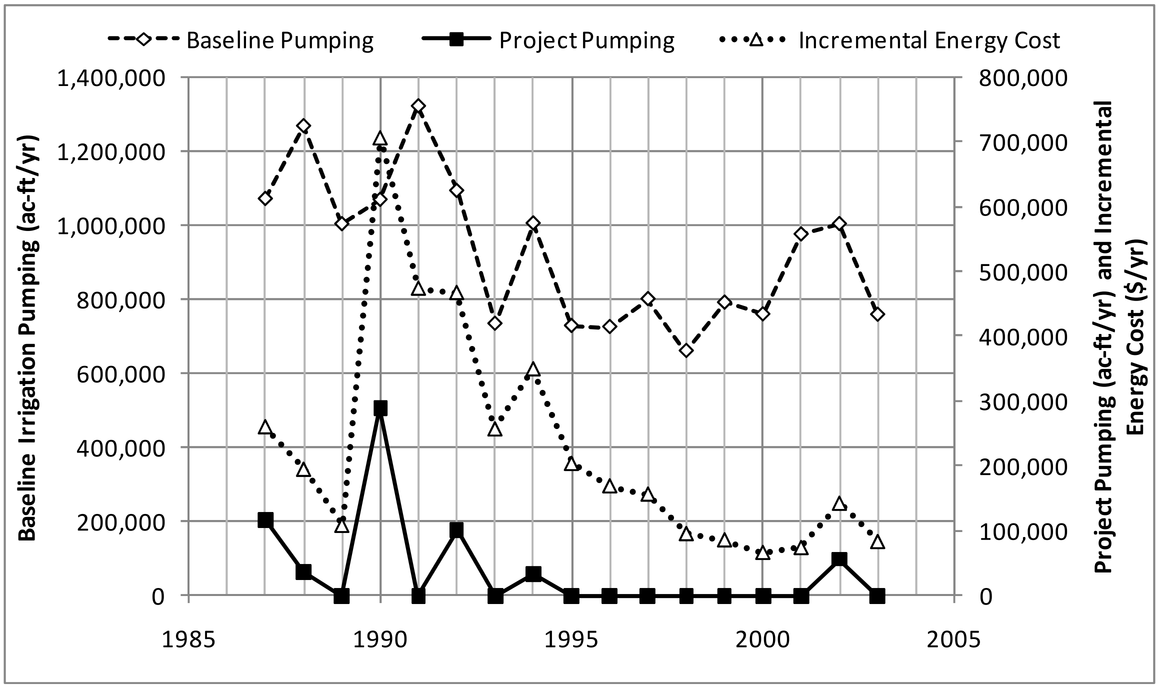

FIGURE 5-28
Annual Baseline Irrigation Pumping, Project Pumping, and Increased Energy Cost: 300 TAF Summer Pumping, New Well Field
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

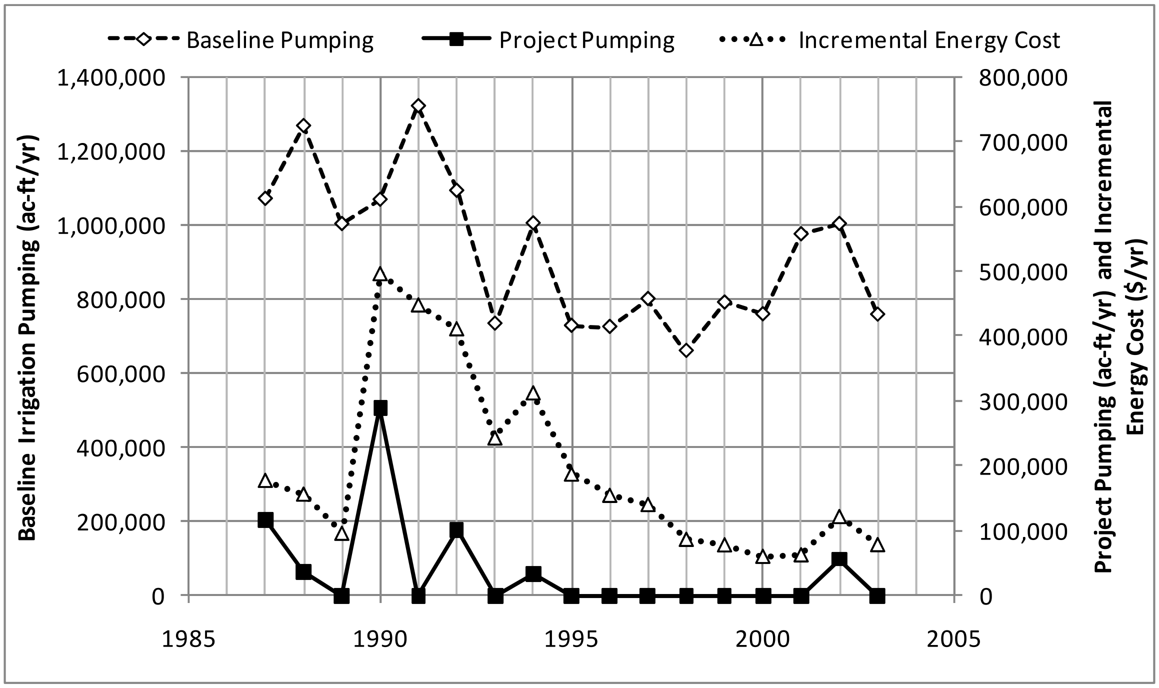

FIGURE 5-29
Annual Baseline Irrigation Pumping, Project Pumping, and Increased Energy Cost: 300 TAF Summer Pumping, Existing Well Field
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Incremental energy costs are greatest in years when project pumping is greatest but are also directly proportional to the amount of baseline irrigation pumping, all else equal. Project pumping in 1990 results in interference drawdown that causes increased lift and associated increased energy costs for the years to follow. The incremental energy costs resulting from Project pumping with the new well field are substantially greater than the incremental energy costs for the existing well field in 1990, the year of maximum pumping in GCID and maximum total project pumping.

Summary statistics of increased annual energy requirements per acre to maintain existing levels of groundwater pumping for non-irrigation (primarily domestic) use are provided for each pumping scenario in Table 5-14. Summary statistics of increased annual energy requirements per acre to maintain existing non-irrigation pumping are provided in Table 5-15. The summary statistics describe the increased energy requirements for 1329 of 1786 sections within the Project area that pump groundwater for non-irrigation uses based on the analysis of year 2000 Census data. Summary statistics of total annual increases to energy costs within the Project area for the 17 years of analysis are provided in Table 5-16.

Similar to the results for irrigation pumping, increases in energy requirements and associated costs are greatest for the 300,000 ac-ft pumping scenarios due to greater interference drawdown resulting from greater Project pumping volumes. Increases in energy requirements are least for the fall pumping scenarios due to the lesser volume of Project pumping (as compared to the 300 TAF summer pumping scenarios) and due to Project pumping occurring after the peak irrigation season, when baseline irrigation pumping is less (non-irrigation pumping, which includes landscape watering for purposes of this analysis, tends to follow a similar distribution as irrigation pumping, with the greatest use during peak demand periods). Costs are similar whether Project pumping relies on a new or existing well field.

TABLE 5-14

Summary Statistics of Increased Annual Energy Requirements Per Acre to Maintain Existing Groundwater Pumping for Non-Irrigation Uses

Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Increased Annual Energy Requirement (kwh/section)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	0.00	2,313.0	15.60	1.05	80.86
300 TAF Summer Pumping, Existing Well Field	0.00	1,951.9	13.38	0.72	71.73
150 TAF Summer Pumping, New Well Field	0.00	1,571.6	9.26	0.65	48.63
150 TAF Summer Pumping, Existing Well Field	0.00	1,864.0	9.18	0.60	50.43
150 TAF Fall Pumping, New Well Field	0.00	1,761.8	10.58	0.69	56.02
150 TAF Fall Pumping, Existing Well Field	0.00	2,038.2	10.62	0.64	58.38
150 TAF Summer & Fall Pumping, New Well Field	0.00	1,675.6	10.32	0.70	53.93
150 TAF Summer & Fall Pumping, Existing Well Field	0.00	1,951.9	10.27	0.65	55.91

TABLE 5-15

Summary Statistics of Increased Annual Energy Costs Per Acre to Maintain Existing Groundwater Pumping for Non-Irrigation Uses

Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Increased Annual Energy Cost ($/section)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	$ -	$ 555.11	$ 3.74	$ 0.25	$ 19.41
300 TAF Summer Pumping, Existing Well Field	$ -	$ 468.47	$ 3.21	$ 0.17	$ 17.21
150 TAF Summer Pumping, New Well Field	$ -	$ 377.18	$ 2.22	$ 0.16	$ 11.67
150 TAF Summer Pumping, Existing Well Field	$ -	$ 447.36	$ 2.20	$ 0.14	$ 12.10
150 TAF Fall Pumping, New Well Field	$ -	$ 422.84	$ 2.54	$ 0.17	$ 13.44
150 TAF Fall Pumping, Existing Well Field	$ -	$ 489.16	$ 2.55	$ 0.15	$ 14.01
150 TAF Summer & Fall Pumping, New Well Field	$ -	$ 402.15	$ 2.48	$ 0.17	$ 12.94
150 TAF Summer & Fall Pumping, Existing Well Field	$ -	$ 468.47	$ 2.46	$ 0.16	$ 13.42

TABLE 5-16

Summary Statistics of Total Increased Annual Energy Costs to Maintain Existing Groundwater Pumping for Non-Irrigation Uses

Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Increased Annual Energy Cost (Total $)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	$ 927	$ 7,823	$ 4,976	$ 4,787	$ 2,218
300 TAF Summer Pumping, Existing Well Field	$ 485	$ 6,962	$ 4,267	$ 4,511	$ 2,058
150 TAF Summer Pumping, New Well Field	$ 839	$ 4,263	$ 2,883	$ 2,680	$ 1,022
150 TAF Summer Pumping, Existing Well Field	$ 613	$ 4,278	$ 2,856	$ 2,757	$ 1,084
150 TAF Fall Pumping, New Well Field	$ 88	$ 5,241	$ 3,374	$ 3,351	$ 1,441
150 TAF Fall Pumping, Existing Well Field	$ 74	$ 5,168	$ 3,315	$ 3,333	$ 1,458
150 TAF Summer & Fall Pumping, New Well Field	$ 512	$ 5,014	$ 3,292	$ 3,155	$ 1,260
150 TAF Summer & Fall Pumping, Existing Well Field	$ 396	$ 4,867	$ 3,207	$ 3,123	$ 1,290

Annual baseline non-irrigation pumping, Project pumping, and increased energy costs by water year are shown for the 300 TAF summer pumping scenario with a new well field in Figure 5-30. Annual baseline irrigation pumping, Project pumping, and increased energy costs by water year are shown for the 300 TAF summer pumping scenario with an existing well field in Figure 5-31. As indicated in the figures, non-irrigation pumping has been assumed to remain constant from year to year for purposes of this analysis.

Incremental energy costs are greatest in years following substantial project pumping. The lag between peak project pumping and peak incremental costs results from gradual reductions in water levels in the shallow aquifer as the regional aquifer and/or lower aquifer is refilled. Interference drawdown in the shallow aquifer in some areas of the Valley may occur more quickly following peak project pumping, but the incremental energy costs may be low if little or no non-irrigation pumping occurs in these areas. The incremental energy costs resulting from project pumping with the new well field are somewhat less than the incremental energy costs for the existing well field but follow a similar trend over time.

In summary, the greatest costs associated with increased lift resulting from interference drawdown will be incurred by agricultural groundwater users due primarily to the greater volume of water pumped. Additionally, project pumping and associated interference drawdown tends to be greatest in agricultural areas away from population centers. Costs are highly variable from location to location and over time but, in aggregate, are similar among pumping scenarios of the same volume (e.g., 300 TAF or 150 TAF). Peak incremental energy costs may occur multiple years after project pumping, particularly for non-irrigation pumping from the shallow aquifer.

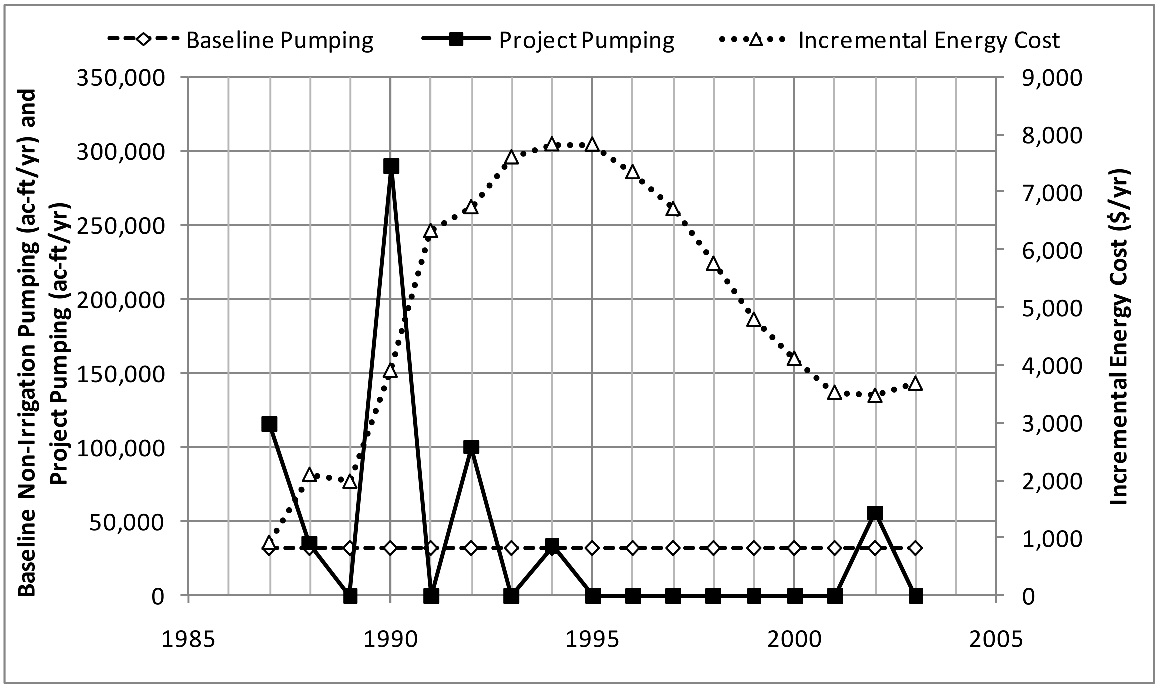

FIGURE 5-30
Annual Baseline Irrigation Pumping, Project Pumping, and Increased Energy Cost: 300 TAF Summer Pumping, New Well Field
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

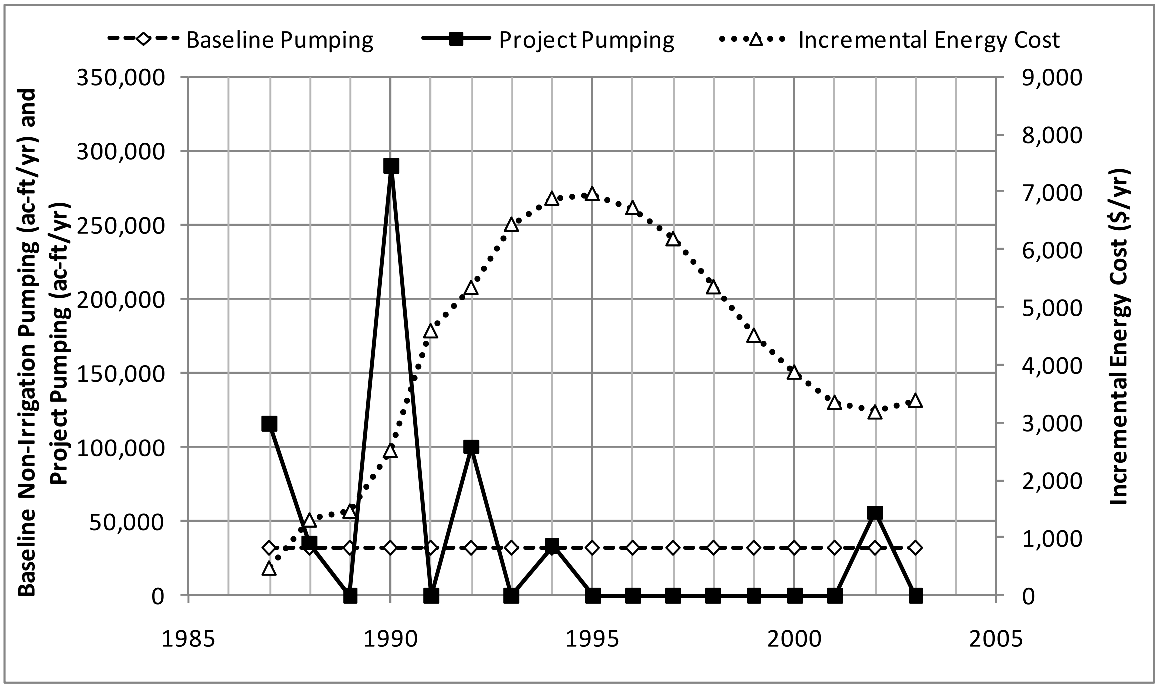

Figure 5-31
Annual Baseline Irrigation Pumping, Project Pumping, and Increased Energy Cost: 300 TAF Summer Pumping, Existing Well Field
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Spreading the payback pumping over two seasons (summer and fall) will moderate the impact. The volume and timing of the pumping will also be efficiently managed by assessing the condition of the groundwater basin in the spring while evaluating its capacity for pumping that year.

If some form or degree of the groundwater pumping payback method is eventually adopted, a mitigation program will be instituted to compensate the owners of the impacted domestic or municipal wells for the expected increase in their pumping cost due to the increased lift.

As yield impacts are not expected at the permissible level and scheduling of the pumping, it should not be necessary to improve their wells or build new and more efficient ones in order to deal with yield impacts.

5.4.1.4. Groundwater Levels

Production of 150 TAF of groundwater from existing wells over the summer/fall period (May through November) results in a maximum of about 30 feet of drawdown in the pumped aquifer compared to a maximum of approximately 40 feet of drawdown if the same production occurs in the summer only.

Simulated drawdown in the vicinity of the eastern well fields in the Butte Basin Project are significantly lower than those observed on the west. This is due to a combination of lower overall production rates from the east and a greater production well spacing.

5.4.2. Impacts on Streamflow

Peak effects on streamflow due to groundwater production in the Sacramento Valley are summarized in Table 5-17.

TABLE 5-17
Peak Effects on Streamflow from Conjunctive Management Operations
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Stream	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
	Existing (cfs)	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**
All Streams	54	53	111	105	80	90	64	65
Butte Creek	13	12	72	69	50	48	39	33
Sacramento River – GCID to Wilkins Slough	42	37	32	28	16	18	16	15
Feather River	3	3	6	6	4	4	4	4
Little Chico Creek	3	3	6	5	4	3	4	3
Salt River	1	5	5	8	2	5	2	5
Stone Coral Creek	6	9	11	15	7	10	6	9
Stony Creek	4	5	7	7	4	6	4	4

Specific conclusions regarding surface water effects are as follows:

The modeled project pumping scenarios result in some streamflow reductions, due either to increased stream loss to aquifers or decreased aquifer flow into streams. To compensate for these losses, the modeling incorporated releases from Shasta and Oroville when the system is “in balance.” Although these releases help maintain streamflow in the Sacramento and Feather Rivers, while insuring the system as whole doesn't experience significant losses, the release do not directly mitigate the impact of *tributary* streamflow losses to ecosystems and species. As a starting point for the assessing impact to tributary streams, the project analyzed Butte Creek due to its high ecosystem value combined with some of the largest discharge losses due to pumping. An additional consideration is that historical streamflow records are available for Butte Creek but generally not for other, smaller tributary streams. The analysis yielded the following key results:

- Project pumping will not impact the uppermost reach in the project areas, the primary spawning area for Spring-run Chinook and Central Valley steelhead
- Pumping will have a greater impact on the lower reaches of Butte Creek, than the upper
    - In addition to cumulative effects, the *rate* of leakage is higher in downstream reaches
- The largest absolute losses in streamflow occur when discharge is also highest (Jan.-Mar)
    - The magnitude of impacts in relation to the baseflow at this time is not substantial (maximum of 1-3% loss in streamflow)
- The largest percentage loss in stream flow occurs in the lowest reach during summer/ early fall when Spring-run have already migrated upstream and steelhead are only beginning to enter the streams
- Project pumping never causes average monthly discharge to fall below the instream flow standards in the four upstream reaches

- June average monthly discharge in the lowermost reach, falls below the 40 cfs instream standard twice in the 17 year record due to pumping of up to 150K, and four times under pumping of up to 300K
    - Most Spring-run migration has already occurred by June, but some late Spring-run migrants, may experience minimal impacts
    - These impacts occur during the drought years of 1990, 1991, 1992, 1994, when Butte County irrigators participated in the drought water bank

The results of the analysis do not reveal any significant negative impact to Spring-run Chinook or Central Valley Steelhead in Butte Creek due to project pumping. Furthermore, this analysis focused only on those years with stream impacts (water years 1987 - 2003), during which time groundwater would have been pumped more frequently than over the entire period assessed by the surface water model (1922-2003). As such, on average impacts would likely be less significant and rarer than those projected in this analysis.

5.4.3. Stream Impact Analysis

The modeled project pumping results in some streamflow reductions, due either to increased stream loss to aquifers or decreased aquifer flow into streams. The greatest impact to surface streams occurs to the Sacramento River, between GCID and Wilkins Slough, and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Project modeling and operations account for the effects of stream leakage when the system is “in balance”, the condition when there is no excess flow in the system and the reservoirs are releasing to satisfy critical conditions. Depending on location and timing of stream leakage, upstream reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. However, if leakage occurs at times when the system is "in surplus", additional reservoir releases may not be necessary. Although this helps maintain flow conditions on the Feather and Sacramento Rivers, as well as minimizing losses to the system as a whole, it does not account for potential stream leakage impacts on fisheries in tributaries, which were examined.

The Sacramento River and several of its tributaries are designated as critical habitat for Spring-run Chinook salmon (SRCS) and Central Valley steelhead, both listed as "threatened" species, as well as the fall and late-fall run Chinook, which are listed as a “species of concern”. The stream analysis in this report focuses on the National Marine and Fisheries Service (NMFS) designated critical habitat within the project area. At this time, the assessment is primarily limited to impact to stream discharge, although other factors, such as water quality parameters, may need to be further assessed if the project proceeds.

The first time pumping occurs within the 17-year groundwater model simulation period (1987 to 2003) is in 1987 to refill Shasta and in 1990 to refill Oroville. Impacts from the initial pumping, as well as additional groundwater pumping in 1988 and 1990 to refill Shasta and in 1992, 1994, and 2002 to refill Oroville, produce stream impacts through 2003. This stream impact analysis focuses only on those years with stream impacts, water years 1987 - 2003. It should be noted that pumping occurred more frequently during this span of the groundwater model than during the longer period assessed by the surface water model (1922-2003). The surface model predicted the need for pumping at most once every seven years, yet pumping occurred six times in the 17-year time span of this analysis.

An initial and conservative assessment of potential pumping impacts to the critical habitat streams in the project area demonstrated that the maximum impact (under up to 300K pumping of existing wells) would yield a less than one cubic foot per second decrease in average monthly streamflow in the majority of critical streams. Table 5-18 lists the streams located in the project area, which are designated as critical habitat for Spring-run Chinook salmon and steelhead, along with the potential impact to streamflow due to pumping.[21] As mentioned above, additional releases from Shasta and Oroville mitigate any negative impact on streamflow in the Sacramento or Feather. The rarity in occurrence of the maximum decrease in discharge, noted in the following table, further nullifies most concerns about any negative impact to fisheries.

The impact to the three highlighted streams (Butte Creek, Little Chico Creek, and Stony Creek) in relation to their actual streamflow did warrant further investigation. The noted ecosystem value of Butte Creek, in conjunction with non-trivial projected project impacts, justified a more in-depth analysis, which is subsequently described. Based on the analysis of Butte Creek, the impact of pumping on Little Chico and Stony Creek, which experience a much less significant loss in stream flow, is determined to also be minimal at this time. If the Project does proceed, more detailed analysis of the impact to Little Chico and Stony Creek may be warranted. With respect to the streamflow impacts, the Project would be operated to assure a net improvement in streamflow parameters important to the viability of protected species, specifically Chinook salmon. Reductions in base flows that may occur in the tributary streams due to additional pumping of groundwater would be more than offset by improvements to environmental flow parameters in the mainstem Sacramento and Feather Rivers and in the resulting inflows to the Delta. Indeed, this Project is designed to contribute substantially to the recovery of these species. That result will be demonstrated to the listing agencies in the consultation process that the CVP, SWP and participating districts will engage in as part of their NEPA/CEQA compliance.

5.5.Economic Analysis

The team compared the costs and benefits of the eight different initial scenarios as a means of evaluating the economic feasibility of the project. This analysis is summarized below.

The economic analysis did not assign a monetary value to the environmental benefits that would be achieved by project ecologic flows releases. This was not because these benefits would be negligible. In fact, the potential increase in salmon productivity could be quite substantial. Rather, methods for valuing environmental benefits are somewhat speculative so, to avoid basing economic feasibility on uncertain benefits, the economic analysis was conducted in part to determine whether the revenue from the project's potential water sales alone would be large enough to pay for the capital and operational costs. Additionally, the benefits that would result from improved groundwater conditions within the Sacramento Valley due to the delivery of additional surface water supplies and consequent relaxation of groundwater pumping were not factored into the economic analysis. In sum, the question was not whether the project would be economically justified, but whether it could pay for itself.

5.5.1. Cost Assessment

The costs of the different scenarios are presented in Table 5-19, including costs capital outlays for project facilities (primarily existing production well rehabilitation or new well construction), project operation and maintenance, compensation for increased pumping costs (ag and domestic), replacement of a certain number of domestic wells and project legal and administrative charges. These costs are described in detail in Appendix E. The present value of these costs based on a real discount

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[21] NOAA. National Marine Fisheries Service - Southwest office. GIS Data. Accessed at: http://swr.nmfs.noaa.gov/salmon/layers/finalgis.htm.

TABLE 5-18
Critical Fish Habitat Areas Assessed in Stream Impact Study
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Critical Habitat		**Maximum Decrease in Mean Monthly Discharge***	
Stream	**Spring-run Chinook**	**Steelhead**	**cfs**	**Comments**
American River	yes	yes	0	No impact
Antelope Creek	yes	yes	0.006	Minimal impact
Bear River	yes	yes	0.008	Minimal impact
Big Chico Creek	yes	yes	0.791	Minimal impact
Butte Creek	yes	yes	26.729	Further study conducted
Butte Creek, Sutter Bypass	yes	yes	Not assessed	Further study conducted
Colusa Bypass	yes	yes	0.962	Minimal impact
Cosumnes River	no	yes	$<10^{-3}$	Minimal impact
Deer Creek	yes	yes	0.056	Minimal impact
Elder Creek	yes	yes	0.049	Minimal impact
Feather River	yes	yes	6.142	Oroville releases to compensate
Little Butte Creek	no	yes	Not assessed	Minimal impact based on Butte Cr. analysis
Little Chico Creek	no	yes	4.875	Minimal impact, but further study may be warranted if the Project proceeds

TABLE 5-18
Critical Fish Habitat Areas Assessed in Stream Impact Study (con't.)
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Stream	**Critical Habitat**		**Maximum Decrease in Mean Monthly Discharge***	
	Spring-run Chinook	**Steelhead**	**cfs**	**Comments**
Little Dry Creek	no	yes	Not assessed	Minimal impact based on Butte Cr. analysis, but further study may be warranted
Mill Creek	yes	yes	0.006	Minimal impact
Mokelumne River	no	yes	$<10^{-4}$	Minimal impact
Paynes Creek	no	yes	$<10^{-4}$	Minimal impact
Putah Creek	no	yes	0.002	Minimal impact
Sacramento Bypass	yes	yes	Not assessed	Shasta releases to compensate
Sac. Deep Water Channel	no	yes	Not assessed	Shasta releases to compensate
Sacramento River	yes	yes	67.795	Shasta releases to compensate
Stony Creek	yes	yes	7.183	Minimal impact, but further study may be warranted if the Project proceeds
Thomes Creek	yes	yes	0.173	Minimal impact
Yuba River	yes	yes	0.044	Minimal impact

TABLE 5-19
Total Cost Associated with the Project for Each Pumping Scenario
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Scenario	Capital	O&M	Dom. & Ag. Energy Compensation	Domestic Well Replacement	Admin & Legal	Total Cost (PV)
1	300 TAF Summer New Wells	$220,604,741	$61,940,720	$3,287,267	$1,776,873	$1,919,003	$289,528,604
2	300 TAF Summer Existing Wells	$140,118,788	$63,962,075	$2,804,880	$3,594,878	$1,919,003	$212,399,624
3	150 TAF Summer New Wells	$108,940,613	$23,368,466	$733,017	$99,285	$1,704,928	$134,846,308
4	150 TAF Summer Existing Wells	$67,481,217	$22,826,909	$777,553	$794,280	$1,704,928	$93,584,886
5	150 TAF Fall New Wells	$176,120,657	$31,067,457	$647,334	$105,034	$1,704,928	$209,645,410
6	150 TAF Fall Existing Wells	$110,980,583	$29,442,275	$727,303	$792,257	$1,704,928	$143,647,345
7	150 TAF Summer & Fall New Wells	$65,364,368	$19,670,551	$721,787	$96,963	$1,704,928	$87,558,597
8	150 TAF Summer & Fall Existing Wells	$42,168,421	$20,133,635	$778,535	$567,088	$1,704,928	$65,352,605

rate of 3 percent ranges from $65M to $298M, with the lower cost scenarios being those relying on existing wells or having longer repayment pumping period and the higher costs scenarios being those relying on new wells and having shorter pumping periods. The scenarios that involve development of new wells are more expensive compared to their sister scenario using existing wells primarily because of the higher capital investment required to build the new wells. The capital cost is almost 60 percent higher to develop new wells than use existing wells.

The results show that the 150 TAF summer and fall pumping scenario using the existing wells is the least expensive scenario. Under the 150 TAF summer and fall pumping scenarios (scenarios 7 and 8) the number of wells required to accommodate project pumping is relatively low because users can withdraw water during a longer period (almost 7 months), which results in a need for fewer wells and the least amount of groundwater level drawdown.

The analysis reveals that the costliest scenarios (in terms of average cost per AF of pumping) are the 150 TAF summer and 150 TAF fall pumping scenarios using new wells (Scenarios 3 and 5) which result in the highest drawdown (Table 5-20). This is due to the shorter pumping period (three or four months) compared to the summer and fall pumping scenarios (seven months). Our analysis shows that the optimal scenario, considering only costs, is the 150 TAF summer and fall pumping scenario using existing wells.

5.5.2. Valuing Benefits

To value the benefits of the additional water supply, potential market value of various time series of additional reservoir releases were considered. The releases will become supplemental streamflow and may be left in the Feather and Sacramento rivers to augment flow, or possibly exported. Benefits are directly linked to the timing of the releases and how far in advance the buyers can be informed about the quantity of these surplus releases. Additional water supplies could be delivered in the Sacramento Valley, or could be left instream to become Delta inflow.

The value of additional water supplies generated through conjunctive operations was estimated in two ways to bracket the economic analysis. Consistent with the in-Valley focus of the investigation one valuation was based on the water being integrated into CVP and SWP project deliveries according to existing water service contracts in the Sacramento Valley. The second valuation, intended to serve as an upper bound, was based on an assumption that the additional supplies could be exported south of the Delta and made available to urban users as a dry year supply[22].

Under the assumption that the water is used within the Sacramento Valley when it is made available, the main feasible uses are groundwater recharge and environmental flows. An examination of water market data reveals that over the past decade, water sold on the Sacramento Valley market for these purposes averaged around $50/AF.[23]

If it were feasible to export the additional water supplies south of the Delta, the additional yield of the project would be worth more. To approximate the value of exportable supplies, the net willingness

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[22] Consistent with the in-Valley scope of the investigation, no analysis was conducted concerning the feasibility of exporting project water supplies. Additional analyses would be needed to determine the frequency with which project releases might be exported and the economic analysis revised accordingly.

[23] Stratecon Inc., "Water Strategist: Analysis of Water Marketing, Finance, Legislation and Litigation," Monthly publications January 2000 – December 2009. The actual average was $57/AF in average to wet hydrologic years.

TABLE 5-20
Average Cost of Pumping and Releases for Each Pumping Scenario
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Scenario	Total Cost (PV)	Pumping Volume (AF)	Avg Cost of Pumping ($/AF)	Avg Annual Releases (AF)	Avg Cost of Annual Releases ($/AF)
1	300 TAF Summer New Wells	$289,528,604	1,307,759	$221	109,596	$79
2	300 TAF Summer Existing Wells	$212,399,624	1,307,759	$162	109,596	$58
3	150 TAF Summer New Wells	$134,846,308	523,547	$258	43,609	$93
4	150 TAF Summer Existing Wells	$93,584,886	523,547	$179	43,609	$64
5	150 TAF Fall New Wells	$209,645,410	608,963	$344	44,298	$142
6	150 TAF Fall Existing Wells	$143,647,345	608,963	$236	44,298	$97
7	150 TAF Summer & Fall New Wells	$87,558,597	574,129	$153	43,955	$60
8	150 TAF Summer & Fall Existing	$65,352,605	574,129	$114	43,955	$45

of urban agencies in the South Coast to pay for dry year water was calculated, and then expenses for conveyance and storage were subtracted, while accounting for carriage and storage losses. Currently, the WD Tier 2 rate for untreated, delivered water is $594/AF.[24] The cost of conveyance to transport the water from Shasta and Oroville to the South Coast is around $220/AF.[25] We used information from Semitropic-Rosamond Water Bank Authority (SRWBA) to approximate the cost of groundwater storage necessary to convert wet year water to dry year water. The volumetric cost of using SRWBA facilities is approximately $230/AF.[26] Water sold south of the Delta will incur storage and carriage losses, which are set at 30 percent based on SRWBA contract terms and pre-Wanger conveyance losses. Taking these numbers together, it follows that the value of additional supply under the assumption that it could be exported through the Delta under pre-Wanger conditions is approximately $100/AF.

It is noted here that under current Delta restrictions, it would not be possible to export additional supplies south of the Delta. To the extent that this option turns out to be economically beneficial, it is another demonstration of the economic cost of current Delta pumping restrictions and the type of benefit that would result from construction of some type of through-or around-Delta conveyance facility.

5.5.3. Results of Economic Analysis

The net benefit of the project considering the associated costs and expected benefits varies depending primarily on where the water can be sold and, to some extent, on whether new wells are constructed or the project is operated using primarily existing wells. As summarized in Table 5-21, if the water generated through conjunctive operations is sold in the Sacramento Valley, only one of the scenarios has a positive net benefit, with the others having modest to strong negative net benefits. In contrast, if the water is valued at export rates, only one of the scenarios has a negative net benefit with the others being positive. Interestingly, even though the 150 TAF summer and fall pumping using the existing wells was the least-cost scenario, the analysis demonstrates that the largest net benefit is associated with the 300 TAF summer pumping scenario using the existing wells (if the water could be exported south of the Delta).

It can be seen from Table 5-21 below that the existing well scenarios dominate the new well scenarios in terms of net benefits. The high capital costs associated with constructing new wells make this option less economically viable.

Overall, Sacramento Valley conjunctive operations appear to be more attractive in the event the additional supplies could be exported south of the Delta.

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[24] MWD rates came from MWD's website: http://www.mwdh2o.com/mwdh2o/pages/finance/ finance_03.html, accessed March 22, 2010

[25] The total conveyance cost is comprised of $1 97/AF for use of the SWP aqueduct and $23 for distribution. Division of Planning and Local Assistance, California Department of Water Resources, "Least Cost Planning and Simulation Model User Manual," 2009.

[26] This storage cost assumes 100,000 shares are purchased in the Antelope Valley Water Bank. The capital payments are $1,662 per share which amortized by multiplying by a 3 percent real interest rate. The annual payments are $12.80 per share for the management fee and $11.70 per share for the maintenance fee. The usage fee is $77.68 per AF for recharge and $77.68 per AF for recovery. In the Antelope Valley Water Bank, one share is equivalent to one acre-foot of water. Semitropic-Rosamond Water Bank Authority, "Rate Structure for Customers," January 20, 2010, accessed at: http://www.semitropic.com/pdfs/SRWBA-Rate%20Structure_Bd%20Adopted1_20_2010.pdf, March 22, 2010

TABLE 5-21
Net Benefit under Various Pumping Scenarios
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Scenario	Annual benefits, local use ($M)	Annual benefits, exports ($M)	Total Cost (PV, $M)	Net benefits, local use ($M)	Net benefits, export ($M)
1 300 TAF Summer New Wells	183	365	290	-107	76
2 300 TAF Summer Existing Wells	183	365	212	-30	153
3 150 TAF Summer New Wells	73	145	135	-62	11
4 150 TAF Summer Existing Wells	73	145	94	-21	52
5 150 TAF Fall New Wells	74	148	210	-136	-62
6 150 TAF Fall Existing Wells	74	148	144	-70	4
7 150 TAF Summer & Fall New Wells	73	147	88	-14	59
8 150 TAF Summer & Fall Existing Wells	73	147	65	8	81

5.6.Provisional Conclusions Guiding Refinement of Scenarios

The main conclusion derived from the formulation and evaluation of preliminary project scenarios is that conjunctive management based on re-operating reservoirs to release additional water supplies for environmental flow enhancements or water supply, backstopped by groundwater pumping when necessary, is hydrologically feasible. Modeling indicates that reservoir re-operation can produce appreciable additional water supplies while meeting all existing CVP and SWP obligations and regulatory requirements governing project operations, provided that groundwater pumping can be exercised when needed. The additional storage space evacuated by making additional reservoir releases is refilled primarily by retaining in storage high flows that otherwise would be released for flood control purposes. Groundwater pumping is called on in only about 1 year in 10, on average, and contributes roughly 10 percent to 20 percent of the reservoir payback with 80 percent to 90 percent of refill coming from surplus surface water that would otherwise have been lost.

Because groundwater is called on infrequently for reservoir payback, impacts to existing groundwater users and to flows in surface streams are modest. Effects on the operability and productivity of existing agricultural wells of additional groundwater pumping to backstop reservoir re-operation are negligible because the estimated changes in groundwater levels are small relative to the screened intervals of agricultural wells. Agricultural pumpers will incur some additional cost for pumping due to the moderately higher lifts caused by drawdown; however, these costs are very small relative to baseline pumping costs and could be mitigated. Because they are much shallower and have shorter screened intervals compared to agricultural wells, it is likely that some existing domestic wells would need to be deepened or replaced. It was estimated that between 6 and 284 domestic wells would need to be replaced depending on assumptions and the scenario considered. This is between 3 and 41 percent of the estimated number of wells in the estimated impact areas (areas with incremental drawdown greater than 2 feet), and between just 0.1 percent and 3 percent of the 9,000+ domestic wells in the region.

The most significant conclusion is that the net benefits of Sacramento Valley conjunctive operations are strongly dependent on where the water could be marketed and the price received. If the water is sold in the Sacramento Valley at current market rates, the project appears not to be economically justified. On the other hand, if the water could be conveyed south of the Delta for storage in a groundwater bank and sold at dry year market rates, the project appears to be economically viable. Of course, such an export operation would require resolution of current Delta conveyance and export constraints and further analysis beyond that performed in this phase of investigation.

Alternatively, if an in-Valley scenario is desired, there is a need to reduce project costs or increase benefits or some combination of the two. One means of reducing costs would be to avoid the large, infrequently utilized capital investments in groundwater production wells by relying to the maximum practical extent on existing groundwater wells. It should be noted, however, that using existing wells rather than constructing new ones does not completely eliminate capital investment because growers would need to be compensated for their sunk costs at a level that would attract them to willingly sell their wells or enter into use agreements. Additionally, some wells would need to be rehabilitated or re-equipped with electrical motors to avoid air emission regulations.

Another potential means of reducing costs would be to employ temporary crop idling as a payback mechanism because crop idling payments would be required only in the years when reservoir payback is triggered.

For purposes of expanding or enhancing project benefits, the decision was made to engage the CVP and SWP operators to see whether they could assist the project team in identifying additional objectives that might achieved through conjunctive operations. Consultation with the CVP and SWP operators is discussed in the next section along with the various refinements made to the surface water model to simulate project operations more realistically and to achieve additional project benefits.

6. Collaboration with CVP and SWP Operators for Refinement of Project Scenarios

6.1.Collaborative Workshops with CVP and SWP Operators

Beginning in April 2010, a series of three ½-day workshops were held with a select group of CVP and SWP operators for the purpose of refining project scenarios. The main purposes were: (1) to identify additional project purposes and benefits that could potentially be realized through conjunctive operations as a means of enhancing project economic performance and (2) to ensure that the simulations were as realistic as possible. The workshops were complemented with one-on-one consultations between operators and project team members as needed to clarify comments and develop specific recommendations for incorporation into scenario development and the supporting modeling methodology. The dates, purposes and outcomes of the workshops are summarized below. Outcomes are discussed in additional detail in the following sections.

- Workshop #1: April 8, 2010. The project team presented the particular conjunctive operations concept being develop (reservoir re-operation with groundwater pumping payback) and an overview of development and performance of the initial project scenarios with particular focus on the surface water model. The main outcomes of the workshop were the following operator recommendations:
    - Update the surface water model to operate from a baseline condition (represented in CALSIM II model outputs) that includes current environmental objectives and constraints (primarily the smelt and salmon BOs)
    - Modify the model to include a forecast-based method for estimating end of year (September) Shasta and Oroville reservoir storage levels (which are used quantifying project assets and project reservoir releases) rather than the method used for initial scenario analysis based on perfect foresight

- Workshop #2: July 9, 2010. The project team presented the refined surface model reflecting the updated CALSIM II baseline with smelt BO and salmon BO operating requirements, and a forecast-based reservoir storage estimating routine. The effects of these changes on project performance were presented and discussed. Further dialogue focused on project operation for additional benefits, including the ability to generate additional environmental flows, support in complying with smelt BO and salmon BO operational requirements, water supply reliability, operational flexibility and cold water pool management in Shasta and Oroville. The main outcome from the meeting was a decision that the project team would work with the CVP and SWP operators to explore two primary interests:
    - Project operations for the purpose of holding water in storage to recover reservoir storage levels
    - Balancing reservoir releases with risk to reservoir carryover storage and related cold water pool management

- Workshop #3: September 9, 2010. A meeting/gaming session was held with operators and the project team at which the surface water model was used to demonstrate effects of additional constraints suggested by the operators in Workshop #2. Generally these constraints reduced project benefits relative to the initial project scenarios and identified areas of risk due to project operations, particularly cold water pool management. Several options for additional analysis were discussed at this meeting, including: revising operator constraints to be less conservative, temperature modeling to refine operating rules, and further modeling to identify system-wide effects.

6.2. Surface Water Model Refinements

The collaborative engagement with CVP and SWP operators resulted in a number of suggestions for refinement to the initial surface water model. Each of these is described below.

6.2.1. Updated CALSIM II Baseline Conditions

As previously explained, the surface water model simulates conjunctive operations by tracking incremental changes from a baseline condition of flows and reservoir storage levels generated by a CALSIM II model run. The CALSIM II baseline used for the initial modeling pre-dated the 2008 Biological Opinion on delta smelt (smelt BO) and the 2009 Biological Opinion on Chinook salmon (salmon BO). The baseline was updated with a CALSIM II model run with the smelt BO and salmon BO included. This baseline was used for further development and evaluation of project scenarios.

6.2.2. Ability to Reduce Shasta Reservoir Releases to Recover Storage

CVP operators expressed concerns about the ability to reduce Shasta releases under conditions when releases are driven by temperature compliance in the Sacramento River below the reservoir rather than water supply demands further downstream. Constraints on the ability to reduce Shasta releases were specified in the form of monthly minimum Keswick releases for temperature compliance, presented below in TABLE 6-1.

TABLE 6-1
Minimum Keswick Release for Temperature Compliance (cfs)
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
6,000	5,000	4,000	4,000	4,000	6,000	7,000	9,000	11,000	13,000	12,000	11,000

The values presented in Table 6-1 are the minimum flows that operators thought were possible while achieving Sacramento River temperature compliance. The significance of these minimum flows is that only the portion of baseline Keswick releases in excess of the minimum flows in TABLE 6- can be held in storage and offset by a similar quantity of groundwater pumping or water made available through crop idling. These minimum Keswick release constraints significantly reduced the ability of the project to recover reservoir storage through reservoir payback mechanisms.

Constraints on the ability to reduce Oroville releases for temperature compliance were specified by SWP operators in a different manner, expressed as a function of Oroville release according to the following Table 6-2.

This constraint allows project operations to recover reservoir storage lowered due to project releases, or to increase carryover storage levels above those in the baseline simulation.

TABLE 6-2
Ability to Reduce Oroville Release (cfs)
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Oroville Release (cfs)	Oct	Nov	Dec-Jun	Jul	Aug	Sep
< 3,000	0	0	0	0	0	0
3,000 – 6,000	500	500	0	500	500	500
> 6,000	1,000	1,000	0	1,000	1,000	1,000

6.2.3. Forecast-Based Operations

The initial surface water model made project asset decisions (volume of additional reservoir release) based on a perfect forecast of September reservoir storage. The implication of this assumption was to minimize the risk of achieving targeted levels of carryover storage due to conjunctive operations. In actual operation, decisions would have to be made based on assumed reservoir inflows and releases to forecast fall reservoir storage. To the extent that actual conditions differ from those assumed for the forecast, actual fall reservoir storage could fall short of certain targets or could impact temperature compliance operations, in some years. The initial model did not simulate these risks.

The surface water model was refined to include a forecast of fall storage conditions based on current reservoir storage, runoff forecasts, and an estimate of reservoir releases from the current month through September. Runoff forecasts at different exceedance levels are used during the spring with more conservative forecasts (user-defined 90 or 99 percent exceedance) used in February and March, respectively. A method to estimate reservoir release volumes was developed for Shasta and Oroville by correlating simulated CalSim II releases with a system-wide CVP water supply index and SWP allocations, respectively. The CVP water supply index is the sum of current storage in Trinity, Shasta, Folsom, and CVP San Luis plus runoff forecasts on the Sacramento and American Rivers, plus Kings River flow to Mendota Pool. The CVP water supply index and runoff forecasts for the Sacramento, Feather, and American Rivers are the same as used in CalSim II for simulation of CVP/SWP operations. Initial correlations were developed and adjusted to balance how forecasted storage compared with CalSim II simulated storage across various year types.

6.2.4. Oroville Carryover Targets

SWP operators expanded a previous project objective related to carryover storage in Lake Oroville. Oroville storage targets were defined to increase carryover storage when at or below 1.5 million acre-feet (MAF) under base conditions by up to a maximum of 200 thousand acre-feet (TAF). These targets were developed to assist in mitigating effects of damage to the low-elevation outlet that occurred during gate testing several years ago. Damage to the low-elevation outlet has effectively increased dead storage in Lake Oroville leading to a desire to increase carryover storage.

6.2.5. Crop Idling for Reservoir Payback

The surface water model was modified to simulate crop idling as a payback mechanism to recover reservoir storage. Assumptions used in the model to simulate crop idling include annual evapotranspiration of applied water (ETAW) for rice (the dominant crop in both project areas), the monthly pattern of ETAW, total number of acres available for crop idling within the project areas, and the decision month for implementing crop idling. An estimate of the maximum total number of acres available for crop idling within each project area was made based on requirements for crop idling contained in an April 2009 Memorandum from the United States Fish and Wildlife Service (USFWS) on

Endangered Species Consultation on the Proposed 2009 Drought Water Bank (2009 USFWS Memo) and the February 2010 Final Environmental Assessment for the 2010-2011 Water Transfer Program (2010 EA) by the United States Bureau of Reclamation (Reclamation). Limitations on acres available for crop idling are established to protect endangered species habitat for the Giant Garter Snake. An additional assumption that no more than 20 percent of the total rice acreage with the project area would be idled in any year was made based maximum potential participation by growers and local acceptability.

Total rice acreage, maximum acres available for crop idling, and maximum annual quantities of surface water made available by crop idling are summarized in TABLE 6-3. Rice ETAW was assumed to be 3.3 acre-feet per acre for the may through September period, distributed monthly as follows: May, 15 percent; June, 22 percent; July and August, 24 percent each; and September, 15 percent.

TABLE 6-3
Summary of Rice Acreage and Maximum Acres for Crop Idling with each Project Area
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Project Area	Total Rice Acreage (acres)	Max. Percent of Acres Idled in Any Year	Max. Acres Idled (acres)	Max. Annual Quantity of Surface Water Made Available by Crop Idling (acre-feet)
GCID	105,000	20%	21,000	69,300
Butte Basin	78,000	20%	15,600	51,480

It was assumed that decisions on acres idled would be made in March, the same decision month for project assets and releases. Compared to decisions involving groundwater pumping for reservoir payback, crop idling decisions must be made earlier in the year, prior to planting before growers make financial outlays for rice production (field preparation, seed, fertilizer, pesticides, and other costs). The earlier decisions necessary for implementing crop idling can result in more frequent crop idling compared to groundwater pumping. Additionally, the fixed pattern of when water is made available with crop idling can result in water made available when it is impossible for it to be held in upstream reservoirs or put to beneficial use downstream. For example, 37 percent of water made available from crop idling occurs in May and June, but it is not possible to reduce Oroville releases in these months (see TABLE 6-2).

6.3.Refined Model Simulation Results

The surface water model was refined to include the first three operator recommendations discussed above; namely, to use an updated CALSIM II baseline; to include restrictions on the extent to which reservoir releases could be reduced due to temperature considerations; and to include a forecast-based estimate of September reservoir levels to use as a basis for calculating project assets and determining additional environmental releases and agricultural deliveries. All of these features make the project simulations more realistic. Once the model was refined, it was used to reevaluate the initial project scenarios and to evaluate the feasibility of operating the project to sustain Oroville carryover storage and using temporary crop idling as a reservoir payback mechanism.

The refined model resulted in differences between how the project operates with the CVP/Shasta Reservoir versus the SWP/ Oroville Reservoir. Therefore results and conclusions are presented below for the CVP and SWP, respectively.

6.3.1. CVP and Shasta Reservoir Results

6.3.1.1. Operations for Core Project Purposes

A comparison of initial and refined simulation results are presented in Table 6-4 for the 100 TAF and 200 TAF GCID project scales (pumping capacity). For the 100 TAF scale, project benefits are reduced by more than 50 percent, from 27 TAF to 12 TAF, with environmental releases reduced by almost two-thirds and agricultural deliveries reduced by half. Corresponding to the reduction in project benefits, reservoir payback is accomplished almost entirely by refill with surplus surface water. Project pumping is reduced from 4 years over the 82-year simulation to just 1 year and the maximum year pumping is reduced from 98 TAF to just 6 TAF. Average annual project pumping was 3 TAF.

TABLE 6-4
Comparison of Initial to Refined Simulation or Project Scenarios (Shasta/CVP)
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

			Project Benefits (TAF)			Reservoir Payback (TAF)			Project Pumping		
Scenario #	Project Scale (Pumping Capacity)	Model	Enviro. Release	Ag. Deliveries	Total Project Benefit	Surplus Surface Water	Project Groundwater Pumping	Total	Number of Years	Peak Year Pumping (TAF)	Peak Pumping Year
1, 3 and 4	100 TAF	Initial	13	14	27	24	3	27	4	98	1990
		Revised	5	7	12	12	0	12	1	6	1976
		Difference	-8	-7	-15	-12	-3	-15	-3	-92	N/A
2	200 TAF	Initial	45	22	67	58	9	67	6	195	1990
		Revised	15	8	23	23	0	23	1	6	1976
		Difference	-30	-14	-44	-35	-9	-44	-5	-189	N/A

Results for the 200 TAF project scale are even more dramatic, with project benefits reduced by roughly two-thirds for both environmental releases and agricultural deliveries. Even at this scale, reservoir refill is accomplished almost entirely with surplus surface water and negligible groundwater pumping.

The dramatically reduced benefits under the refined operations are due primarily to the effects of forecast-based operations added to the model. The forecast of September storage is deliberately conservative to avoid excess risk to reservoir storage; it is based on a 90 percent exceedance forecast for March runoff and 50 percent exceedance in later months. This frequently results in an under estimation of available project assets and therefore much smaller reservoir releases for environmental flows and agricultural water supplies compared to the initial modeling based on perfect storage forecasts.

The minimum Shasta (Keswick) release constraints prescribed by the operators, together with the forecast-based simulation, also resulted in some additional risk to reservoir carryover storage relative to baseline conditions. The risk was greatest when Shasta storage is below 2.0 MAF when project releases in one year are not refilled from surplus surface water in subsequent years and the project is not able to recover the storage deficit due to an inability to reduce reservoir releases and retain payback water into Shasta. The project is not able to recover the storage deficit due to the minimum Keswick release requirement prescribed by operators for purposes of complying with Sacramento River temperature requirements for protection of endangered species. Simulated project operations resulted in slightly diminished ability to meet Shasta carryover targets specified in the salmon BO relative to the CALSIM II baseline.

Because the minimum Keswick releases had such a strong effect on project performance, the model was used to test the sensitivity of Shasta carryover storage to relaxed minimum release targets relative to those specified by the operators. Relaxing the minimum releases by 2,000 cfs in all months (relative to those listed in Table 6-1) revealed only limited potential to improve carryover storage conditions when below approximately 2.0 MAF. Because of the significant constraints posed to project operation by the Keswick releases, it was concluded that temperature modeling should be performed to better evaluate relaxed minimum reservoir releases and the resulting implications to temperature compliance operations.

6.3.1.2. *Effectiveness of Temporary Crop Idling as a Payback Mechanism*

The operator-prescribed constraints on the ability to retain payback water in Lake Shasta discussed above also apply to crop idling. However, there are additional factors associated with crop idling related to the timing of decision making and the inflexibility in when the water is produced that affect its performance as a payback mechanism.

As previously explained, crop idling decisions need to be made earlier in the season and involve making an irreversible commitment to participating growers for purchasing the water generated through crop idling regardless of whether or not the water can be held in upstream storage or put to beneficial use downstream.

A scenario was evaluated where idling provided 70 TAF of payback capacity (requiring idling of 21,000 acres of rice land) and groundwater pumping 130 TAF to achieve a total of 200 TAF of payback in GCID (corresponding to Scenario 2). Payback priority was placed on crop idling in order to minimize groundwater pumping. Under these assumed conditions, crop idling was called on about 1/3 of the time during the 82-year simulation, in most cases utilizing the maximum 70 TAF of payback capacity and associated land idling (21,000 acres). It was found that only 17 percent of the water generated by idling was actually retained in Shasta to recover reservoir storage due to much of the water being produced when minimum Shasta releases for temperature control were controlling. It was shown that the effectiveness of crop idling is sensitive to the magnitude of the specified minimum releases. When releases were relaxed by 2,000 cfs in all months as described above, the portion of idling payback water retained in storage increased to 58 percent and the frequency with which idling was called on was reduced.

As expected, placing priority on idling for reservoir payback was found to appreciably reduce the magnitude of groundwater pumping needed for Shasta payback.

While the effectiveness of crop idling probably could be improved through refinement in when and how it is called on, and despite the fact that it can be used to offset groundwater pumping for payback, it is doubtful that crop idling offers a cost-effective means of reservoir payback due to the risks associated with the early timing of the decision, the irreversible commitment to follow through once a decision has been made, and the inflexible pattern on which water is made available.

6.3.1.3. *Operation for Cold Water Pool Management*

During collaborative discussions with operators, interest was expressed in evaluating how project operations could be used to improve carryover storage and management of cold water resources in Lake Shasta. An additional analysis was conducted with the refined surface water model to estimate the upper limit of potential project contributions to carryover storage (based on 200 TAF of pumping capacity in GCID). The minimum Keswick release constraints discussed above were maintained for this analysis; however, it was assumed that project pumping capacity would be used whenever it was possible to back water into storage, regardless of storage conditions.

This analysis revealed that project pumping frequency and magnitude were significantly increased relative to the levels observed for operations for generating additional reservoir releases, probably to levels that would be problematic from the standpoint of groundwater impacts. Additionally, the analysis showed that most of the water placed in storage was subsequently lost as reservoir spillage due to the high probability of reservoir refill from runoff. This scenario was simulated with only groundwater pumping as a payback mechanism to simplify the analysis. Although crop idling is not precluded as a payback mechanism and could be explored, it is likely that it would perform even less efficiently due to the issues discussed above.

Operating the project in this manner to maintain Shasta storage is fundamentally in conflict with operations for increasing reservoir releases to generate project benefits; nevertheless, project reservoir releases were included in the simulation because they are fundamental to the project goals. As expected, benefits increase slightly due to project water stored in Shasta in previous years being available in subsequent years for release.

This scenario could be refined to limit pumping based on Shasta storage, thereby reducing both pumping and project spills and creating a more efficient operation; however, the high probability of reservoir refill from runoff puts project generated storage at high risk of spilling. Additionally, the relatively high frequency and large magnitudes of pumping involved would likely create unacceptable impacts. The scenario was useful for understanding the upper limit of conjunctive operations to increase carryover storage but it does not appear to be a feasible mode of project operation.

6.3.1.4. Yolo Bypass Inundation

The CVP and SWP operators also expressed interest in evaluating methods to increase the frequency, duration, and magnitude of flooding in the Yolo Bypass. Results from the initial analyses indicated the Yolo Bypass could be inundated more frequently if it was possible to notch the Fremont Weir, which currently blocks flow into the bypass below certain river stages, to allow inundation at lower river stages and flows. Weir modifications were the cause of increased Yolo Bypass inundation in 19 out of 20 years when the project (as opposed to base operations) inundated the bypass in the phase 1 analysis. Increased project releases inundated the bypass in the other year.

An additional analysis was conducted with the refined surface water model to estimate the upper limit of the ability of the project to increase inundation in the Yolo Bypass. This analysis included turning off all other environmental objectives to ensure inundation was the first priority objective every year and would not be affected by releases for lower priority objectives in previous years. It was revealed that the project would enable Yolo Bypass inundation in an additional 20 years relative to baseline operations; however, as with the initial analysis, all 20 years were due to weir modification, not additional project release. Therefore, in all years the water cost associated with inundating the Yolo Bypass exceeded project assets. This is not an unexpected result given the significant reduction in project assets caused by the addition of forecast-based operations as recommended by the project operators.

6.3.2. SWP and Oroville Reservoir Results

The results discussed below are for simulations made with the addition of forecast-based operations, restrictions on ability to reduce Oroville releases, and addition of carryover storage targets as described above. Additionally, it should be noted that updating the base conditions to include the smelt and salmon BOs had a more significant effect on Oroville operation than on Shasta operations. Operations under the smelt BO and salmon BO result in lower storage in Oroville. This occurs because winter and spring Delta export restrictions reduce the SWP's ability to capture Delta surplus in those months, which results in increased reliance on Oroville storage releases into the Delta in the summer and early fall.

6.3.2.1. *Operations for Core Project Purposes*

A comparison of initial and refined simulation results are presented in Table 6-5 for the 50 TAF and 100 TAF Butte Basin project scales (pumping capacity). For the 50 TAF scale, project benefits are reduced by about 40 percent, from 17 TAF to 10 TAF, with agricultural deliveries being reduced by 50 percent and environmental releases by 30 percent. For both the initial and refined simulation about 80 percent of reservoir refill is accomplished by surplus surface water and 20 percent by project pumping, although the total refill is reduced in the refined simulation corresponding to the reduction in project benefits. Average annual project pumping is reduced from 3 TAF to 2 TAF, but the number of years of pumping and peak annual pumping are not appreciably reduced.

The disproportionate reduction of agricultural benefits noted above is due to the combination of lower base storage conditions, higher carryover storage targets, and assumptions on additional agricultural demands that are based on water year types. Lower base storages combined with higher carryover storage targets reduce the frequency and volume of project assets and typically result in assets being available in only wetter year types (when agricultural shortages tend not to occur). Additional agricultural demands are assumed to be higher in drier year types, when project assets are less, thereby reducing average annual project agricultural deliveries and shifting more of the deliveries into wetter year types. Overall, project benefits are reduced by 30 percent relative to the initial 100 TAF Butte Basin scenario.

TABLE 6-5
Comparison of Initial to Refined Simulation of Project Scenarios (Oroville/SWP)
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			Project Benefits (TAF)			**Reservoir Payback (TAF)**			**Project Pumping**		
Scenario #	**Project Scale (Pumping Capacity)**	**Model**	**Enviro. Release**	**Ag. Deliveries**	**Total Project Benefit**	**Surplus Surface Water**	**Project Groundwater Pumping**	**Total**	**Number of Years**	**Peak Year Pumping (TAF)**	**Peak Pumping Year**
1, 3 and 4	50 TAF	Initial	7	10	17	14	3	17	6	50	1961, 1992
		Revised	5	5	10	8	2	10	5	49	1925
		Difference	-2	-5	-7	-6	-1	-7	-1	-1	N/A
2	100 TAF	Initial	23	20	43	36	7	43	8	100	1961, 1992
		Revised	18	9	27	24	3	27	6	99	1925
		Difference	-5	-11	-16	-12	-4	-16	-2	-1	N/A

Modification of carryover storage targets results in more frequent project pumping (or crop idling) and spill of project water stored in Oroville. Average annual pumping increases from

Additional pumping and storage also provides a slight increase in project agricultural and environmental benefits because water stored in Oroville is a project asset and available for meeting project objectives in future years. This results in a less efficient operation (with efficiency defined as refill of project releases for agricultural and environmental purposes from capture of surplus surface water as opposed to groundwater pumping), but a similar level of benefits.

6.3.2.2. *Effectiveness of Temporary Crop Idling as a Payback Mechanism*

As noted above (see Table 6-4), crop idling in the Butte Basin has the potential to provide approximately 50 TAF of water in a year by idling approximately 15,600 acres, or 20 percent of the rice acreage in Western Canal Water District and Richvale Irrigation District. A scenario was evaluated where idling provided the 50 TAF of payback capacity noted above and groundwater pumping 50 TAF to achieve a total of 100 TAF of payback in GCID (corresponding to Scenario 2). Payback priority was placed on crop idling in order to minimize groundwater pumping.

Under these assumed conditions, crop idling was called on about 40 percent of the time during the 82-year simulation, in most cases utilizing the maximum 50 TAF of payback capacity and associated land idling (15,600 acres). It was found that about 50 percent of the 23 TAF of water generated by crop idling was retained in Oroville to recover reservoir storage with the remainder spilled.

As expected, placing priority on idling for reservoir payback was found to appreciably reduce the magnitude of groundwater pumping needed for Oroville payback. Average annual payback pumping was reduced from 20 TAF to 10 TAF.

6.4. Conclusions Drawn from Refined Model and Scenario Analyses

Several conclusions were drawn from the refined modeling and scenario analyses to guide development of project scenarios that are most likely to provide cost-effective opportunities for achieving the environmental and water supply benefits possible through conjunctive operation Sacramento Valley surface water and groundwater reservoirs. These conclusions are discussed below:

1. The input and recommendations provided by CVP and SWP operators for refining project scenarios reflect the challenges and risks that they routinely face in balancing project operations for water supply and complying with environmental regulations governing project operations. In particular, as described above, project operators were primarily interested in conjunctive operations for the purpose of maintaining reservoir levels when reservoir storage dropped below certain thresholds as a means of observing carryover storage and increasing the probability of complying with temperature standards. While logical from a risk management perspective, operating conjunctively for this purpose cuts deeply into the ability to generate additional water supplies for environmental releases and water supply. Additionally, the efficiency of reservoir payback operations is reduced appreciably because much of the project water placed in storage eventually spills due to subsequent reservoir refill from surplus flows.

   These findings reveal important and complex tradeoffs among environmental objectives that are embedded in project operations. By definition, producing additional water supplies to dedicate to environmental flows without infringing on base supplies to CVP and SWP contractors involves making additional reservoir releases. However, increasing reservoir releases reduces reservoir storage and unavoidably introduces some additional risk to coldwater pool management.

2. The minimum Keswick releases specified by the CVP operators as surrogates for temperature targets in the Sacramento River dramatically reduce the effectiveness of reservoir payback operations because payback is possible only when reservoir releases exceed the minimum specified values. This reduces the time during which water generated by payback operations can actually be used to offset reservoir releases. This is another manifestation of the tradeoffs among environmental objectives, with the objective of maintaining river temperature constraining the ability to operate conjunctively for other environmental benefits.

3. The general conclusion to be drawn from 1) and 2) above is that the tradeoffs among environmental objectives call for further investigation and development of operating strategies and criteria that best balance competing objectives for maximum net environmental benefit.

Addressing this need is foundational to moving ahead with development of conjunctive management strategies for the Sacramento Valley. However, until tradeoffs among environmental objectives are reconciled, planning must account for the operational constraints as they are currently defined.

4. Crop idling is an inefficient payback mechanism in comparison to groundwater pumping. The main reasons are that crop idling must be triggered early in the year before farmers commit to planting crops, which introduces additional risk in forecasting the need for the payback water, and that once the commitment is made, it cannot be undone. These factors result in frequent, unnecessary crop idling with associated lost production, with much of the water made available being lost as reservoir spillage or surplus Delta outflow. The original attraction to temporary crop idling was that it does not require up front capital investment and can be exercised as needed on a year to year basis. However, the inefficiencies revealed through the simulations suggest that crop idling is likely to be a less viable, and undoubtedly less acceptable, payback mechanism as compared to groundwater pumping, especially if pumping can be achieved with existing groundwater production wells to minimize required capital inputs.

5. All of the various suggestions for refinement of the project scenarios and model have the effect of either reducing project benefits (relative to the initial analysis) or reducing the efficiency of payback operations, thereby detracting from project cost-effectiveness.

Based on these conclusions, further planning and modeling proceeded within a framework defined by the following parameters:

1. The project baseline will be represented by a CALSIM II run that includes the effects of the smelt and salmon BO's.

2. Forecast based operations will be used because they are more realistic.

3. Restrictions on reservoir releases as specified by CVP and SWP operators will be observed because they are the best available representation of temperature compliance conditions.

4. The objective will be to generate benefits through additional environmental releases and water supplies, not through operations to sustain reservoir levels.

5. Payback operations will be based on groundwater pumping, not temporary crop idling.

6.5. Analysis of Project Scale

Within the planning and modeling framework defined above, a set of model runs was made for the two project areas to examine the relationship between project payback capacity, simulated project pumping and project benefits. In addition to the parameters specified above, a decision was made to use a summer and fall payback pumping period, rather than summer only, to maximize the opportunity for payback operations, thereby minimizing the constraint posed by minimum reservoir releases. The results are presented and discussed separately for the two project areas.

6.5.1. GCID/CVP-Shasta

A set of 11 model runs were made with specified payback pumping ranging from 20 TAF to 300 TAF and all other model parameters held constant. This wide range was selected to better understand project performance from the surface water perspective and does not reflect an assumption or an assertion that annual pumping volumes of up to 300 TAF would be feasible in GCID. Results are summarized Table 6-6.

TABLE 6-6
GCID/CVP-Shasta Average Annual Project Benefits, Reservoir Payback and Project Pumping in Relation to Project Pumping Capacity
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Avg. Annual Project Benefits (TAF)			Average Annual Reservoir Payback (TAF)			Project Pumping		
Payback Pumping Capacity	Enviro. Release	Ag. Deliveries	Total	Surplus Surface Water	Groundwater Pumping	Total	Peak Annual Pumping	Percentage of Payback Capacity Used	Peak Pumping Year
20	0	3	3	3	0	3	3	15%	1930
40	1	4	5	5	0	5	6	15%	1930
60	3	4	7	7	0	7	9	15%	1930
80	4	5	9	9	0	9	11	14%	1930
100	5	7	12	12	0	12	11	11%	1930
120	7	8	15	15	0	15	11	9%	1930
150	11	8	19	19	0	19	11	7%	1930
200	15	8	23	23	0	23	11	6%	1930
240	20	9	29	28	1	29	96	40%	1939
270	24	7	31	30	1	31	98	36%	1939
300	25	7	32	30	2	32	98	33%	1939

It can be seen that, as pumping capacity increases, average annual project benefits are initially weighted in favor of agricultural deliveries but then switch in favor of environmental releases when capacity exceeds about 120 TAF. This is due primarily to environmental release targets being large and being made only when they can be completely satisfied. Smaller pumping capacities and associated project assets reduce the likelihood of being able to make these large releases. In contrast, agricultural deliveries are typically smaller than environmental releases and do not need to be fully satisfied; thus, some agricultural releases are possible even with very small project pumping capacities. Project benefits in relation to project pumping capacity are plotted in Figure 6-1.

It is important to note that the average annual total project benefit (sum of environmental releases and agricultural deliveries) is much smaller than the specified pumping capacity over the full capacity range evaluated. As previously discussed, this stems primarily from the nature of forecast-based operations and the associated conservative estimates of project assets used to avoid excessive risk to reservoir storage.

As expected, average annual reservoir payback is weighted strongly in favor of surplus surface water over the full range of pumping capacity, due to priority being placed on refill from surplus surface flows and pumping being called on only when needed. Simulated average annual project pumping is negligible until the specified pumping capacity exceeds 200 TAF, and then is modest on an average annual basis.

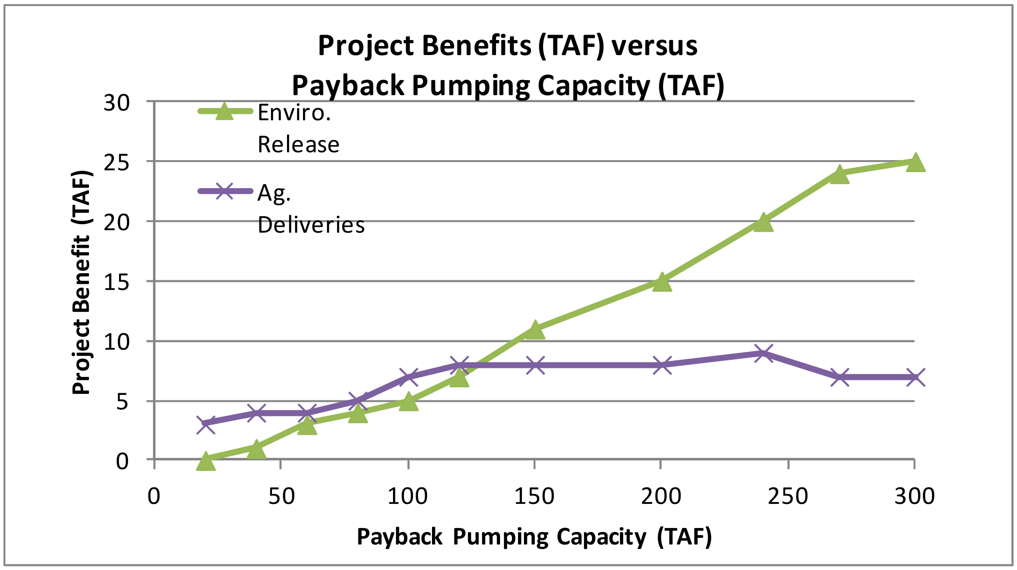

FIGURE 6-1
GCID/CVP-Shasta Average Annual Project Benefits in Relation to Payback Pumping Capacity
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Peak year pumping is negligible below a pumping capacity of 200 TAF, ranging between 3 TAF and 11 TAF (Table 6-6, Figure 6-2). Above pumping capacity 200 TAF, when larger project assets are available and large environmental releases become possible, peak year pumping increases appreciably, utilizing more of the available pumping capacity. However, even at these levels, simulated peak year pumping is less than half of the pumping capacity. This is explained by the same factors discussed above in relation project benefits being small in relation to pumping capacity. Additionally, simulated pumping is constrained when minimum Keswick releases govern and it is not possible to hold payback water in storage.

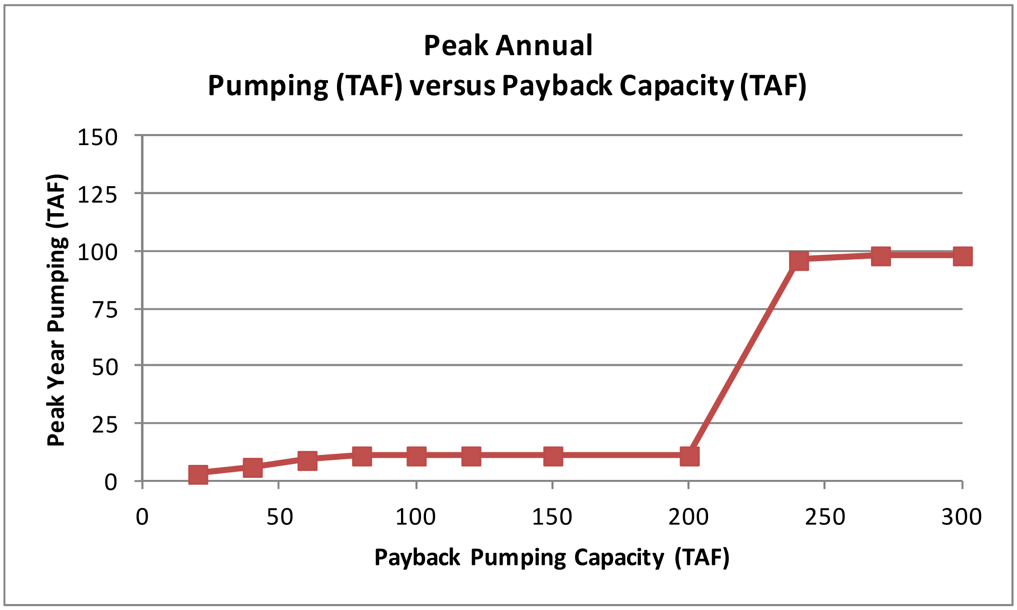

FIGURE 6-2
GCID/CVP-Shasta Peak Annual Project Pumping in Relation to Payback Pumping Capacity
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

6.5.2. Butte Basin/SWP-Oroville

A set of model runs analogous to those made for GCID were also made for the Butte Basin, with specified payback pumping ranging from 20 TAF to 300 TAF and all other model parameters held constant. As noted above, this wide range was selected to better understand project performance from the surface water perspective and does not reflect an assumption or an assertion that annual pumping volumes of up to 300 TAF would be feasible in Butte Basin. Results, summarized in Table 6-7, are similar to those for GCID, with certain exceptions.

TABLE 6-7
Butte Basin/SWP-Oroville Average Annual Project Benefits, Reservoir Payback and Project Pumping in Relation to Project Pumping Capacity
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

	Avg. Annual Project Benefits (TAF)			Average Annual Reservoir Payback (TAF)			Project Pumping		
Payback Pumping Capacity	Enviro. Release	Ag. Deliveries	Total	Surplus Surface Water	Groundwater Pumping	Total	Peak Annual Pumping	Percentage of Payback Capacity Used	Peak Pumping Year
20	0	3	3	2	1	3	12	60%	1925
40	3	4	7	6	1	7	24	60%	1925
60	8	5	13	11	1	12	36	60%	1925
80	13	7	20	17	2	19	48	60%	1925
100	18	9	27	24	3	27	59	59%	1925
120	19	10	29	26	3	29	71	59%	1925
150	19	11	30	26	4	30	89	59%	1925
200	23	9	32	29	4	33	91	46%	1925
240	36	10	46	41	4	45	125	52%	1955
270	42	11	53	47	5	52	130	48%	1955
300	51	10	61	55	5	60	130	43%	1955

Similar to GCID, as pumping capacity increases, average annual project benefits are initially weighted in favor of agricultural deliveries but switch more quickly in favor of environmental releases. Above about 40 TAF of pumping capacity, environmental benefits gradually increase while agricultural deliveries plateau at about 10 TAF above 100 TAF of capacity. The factors explaining this are generally the same as for GCID. Project benefits in relation to project pumping capacity are plotted in Figure 6-3.

As in GCID, the average annual total project benefit (sum of environmental releases and agricultural deliveries) is small relative to the specified pumping capacity over the full capacity range evaluated.

As expected, average annual reservoir payback is weighted strongly in favor of surplus surface water over the full range of pumping capacity, due to priority being placed on refill from surplus surface flows and pumping being called on only when needed. However, in contrast to GCID, both refill from surplus surface water and from project pumping increase gradually over the full range of project pumping.

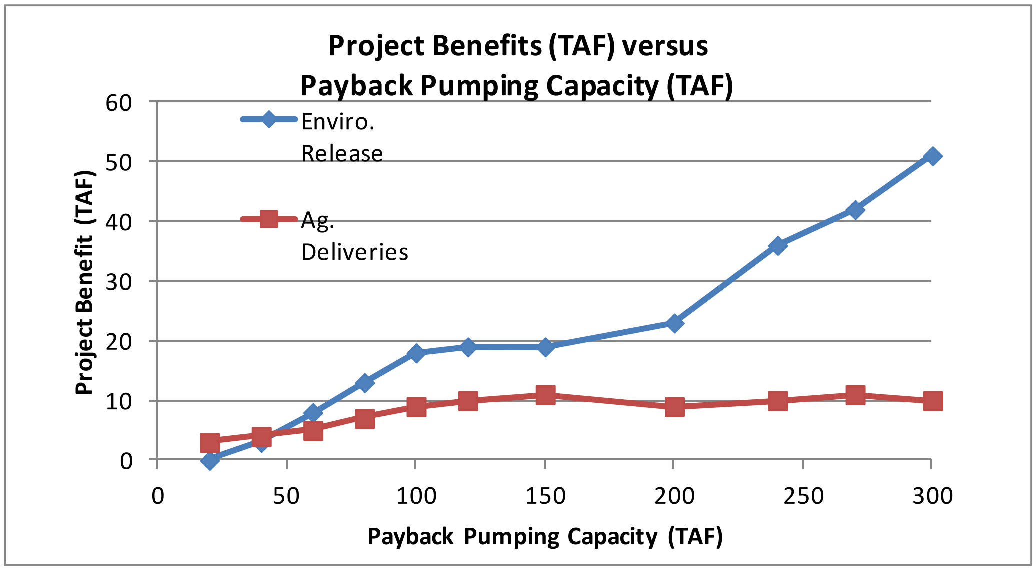

FIGURE 6-3
Butte Basin/SWP-Oroville Average Annual Project Benefits in Relation to Payback Pumping Capacity
Northern Sacramento Valley Conjunctive Water Management Investigation Final Report

Somewhat different than in GCID, peak year pumping increases more or less in proportion and is larger relative to project pumping capacity (Table 6-7, Figure 6-4). Peak year pumping ranges from 12 TAF to 130 TAF, representing between 43 percent and 60 percent of specified pumping capacity.

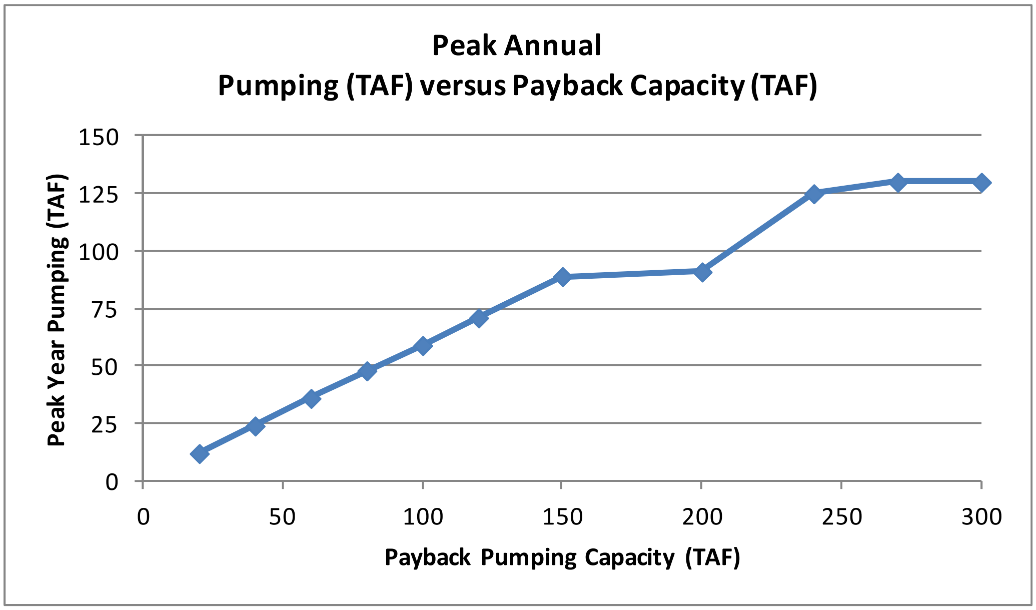

FIGURE 6-4
Butte Basin/SWP-Oroville Peak Annual Project Pumping in Relation to Payback Pumping Capacity
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6.5.3. Discussion

The most important revelation from the foregoing analysis of project scale is the significant underutilization of payback pumping capacity in both project locations. Over the 82-year period of analysis and the range of payback capacities evaluated (20 TAF to 300 TAF), the maximum annual payback pumping in GCID was just 40 percent (at 240 TAF capacity; see Table 6-7) and was just 60 percent of capacity in Butte Basin (between capacity 20 and 80 cfs; see Table 6-7). Average annual pumping is even more extreme in both locations, with less than 1 percent of capacity used on average in GCID and less than 2 percent used on average in Butte Basin.

The low utilization of project pumping capacity stems in part from the conservative nature of the forecast September reservoir storage, which tends to underestimate project assets, and in part from constraints on payback pumping posed by minimum reservoir releases made for temperature control purposes. However, regardless of its cause, the low utilization of project pumping capacity combined with its high capital cost is economically infeasible and indicates that other approaches should be pursued to enhance project economics. One alternative would be to not attempt to recover reservoir levels reduced by project operations and instead incur some level of increased risk that CVP and SWP water deliveries would be reduced. This approach violates one of the original project principles, but may be a reasonable solution all factors considered. This idea is explored further as a recommendation for further investigation (see Section 7).

7. Recommendations for Further Investigation

The seminal conclusion of this investigation is that re-operating Shasta and Oroville Reservoirs in conjunction with operation of Sacramento Valley groundwater aquifers could produce appreciable additional water supplies with low risk to CVP and SWP reservoir storage levels and water deliveries, including requirements to maintain environmentally mandated water temperatures under most conditions. While an economically feasible in-Valley operation scenario was not identified by the investigation, prospects of a viable formulation appear promising and further development and integration of the core concept appears warranted.

The particular topics described in the following sections are in the opinion of the project team the highest priority issues to be addressed moving ahead. These are primarily technical in nature, involving reconciling tradeoffs among different types of environmental water uses, more detailed water temperature modeling, refined reservoir payback operations, integration with south of Delta groundwater banking and refinement of analytic tools.

Beyond the technical factors lie significant institutional and social challenges that would need to be addressed if there is sufficient interest in advancing the project toward implementation. These include the following:

- Developing protocols and procedures for real-time operations decisionmaking that are more nuanced and realistic than the procedures and criteria that have been used to simulate conjunctive operations for planning purposes. Ultimately, these procedures would need to be integrated into the Coordinated Operations Agreement, which governs the combined operation of the CVP and SWP.

- Developing project governance structures among local political jurisdictions. This phase of project planning was conducted without regard to ultimate project sponsorship. The presumption, however, is that a Sacramento Valley conjunctive water management project like that described in this document would most logically be sponsored and operated by a coalition of local political jurisdictions, potentially including counties and existing water suppliers (local districts).

- Developing formulae for allocating project benefits and costs, which would be needed to develop plan for financing project implementation, if the project moves ahead.

7.1.Reconcile Tradeoffs among Environmental Project Functions

A major revelation of this investigation is that opportunities for enhancement of Sacramento and Feather River ecologic functions (as well as opportunities to produce additional water supplies for in-Valley uses) are dramatically constrained by existing environmental requirements placed on CVP and SWP operations. In particular, the study revealed that CVP operations are frequently governed by releases for temperature compliance in the Sacramento River below Shasta, which has the effect of reducing the ability to recover Shasta by project pumping because pumped water cannot be retained in storage. In effect, the magnitude of the water asset that could be developed through conjunctive operations is diminished, which reduces the ability to fulfill the geomorphic, flood plain inundation and spring pulse flow objectives identified by the study.

Efforts are urgently needed to establish the relative benefits of alternative, competing environmental water uses so that ecosystem functions can be restored and species can be recovered while overall water use efficiency is enhanced. This calls for cooperation and compromise among the various fish and wildlife management agencies as well as ongoing research and adaptive management.

7.2.Refine Reservoir Operation Rules Based on Temperature Modeling

In the simulations conducted for this investigation, water temperature objectives were represented indirectly by minimum reservoir releases provided by project operators. These flows are based on operator judgment and provided useful guidance for investigation thus far. However, because the minimum flows were found to dramatically reduce the efficiency of payback operations, as noted above, it is recommended that more sensitive operating rules be developed through application of temperature models.

The recommended approach is to conduct a series of parametric CALSIM II model runs where operating objectives and constraints are held constant while minimum reservoir releases are varied over a range between the relatively conservative flows that were used in this investigation down to flows that would likely be inadequate to achieve temperature targets. Then one (or possibly more) of the existing temperature models would operate on the CALSIM II outputs to estimate the water temperatures that would occur under each flow regime. This would presumably provide insights into the nature of water temperature fluctuations as they relate to flows, time of year and other factors, and provide a basis for developing more sensitive operating rules. The refined rules would then be incorporated into the surface water model for use in formulating, comparing and evaluating project scenarios.

7.3.Refine Reservoir Payback Pumping Strategies and Costs

The investigation revealed that developing new groundwater production wells for payback pumping is not cost-effective because the wells are expensive, they are called on only infrequently and their operation for recovering reservoirs is limited by other operation requirements, particularly, by reservoir releases made to comply with temperature requirements. Large investment in capital works that are rarely used simply does not make good economic sense. This is why temporary crop idling was investigated as an alternative payback mechanism, because costs are incurred only when idling is called on. Unfortunately, however, crop idling is not compatible with the project’s operational requirements and would be triggered in many cases when it is not ultimately needed or the water generated cannot be held in storage.

In the next phase of work, three alternative payback strategies should be explored. Each of these is described below; however, it should be kept in mind that the strategies could be combined for optimal project performance.

7.3.1. Revised Temporary Crop Idling

The investigation revealed that temporary crop idling is not an efficient form of reservoir payback, mainly because much of the water generated by crop idling is either later found to not be needed or is stored in project reservoirs and subsequently spills. These outcomes result from the decision to exercise crop idling being made in February when forecasts of September reservoir storage are relatively uncertain. Once made the commitment to idle land (by paying voluntarily enrolled growers) is irreversible and the water generated is frequently not used.

Rather than make the decision to idle land in February, the possibly of making the decision later, when better forecasts of reservoir storage can be made, should be explored. Under this arrangement, growers would commit to growing their crops but they would enter voluntarily into agreements that would allow the project to interrupt water supplies at any time. For example, a grower might commit to growing a corn crop on the usual schedule with a certain probability that he would be asked to suspend irrigation with surface sometime during the crop season. He would be required to suspend irrigation in exchange for payments designed to compensate for lost production. (Alternatively, the grower could access a groundwater source and continuing irrigation. The farther into the season the idling call was made, the more incentive the grower would have to find an alternative water supply to finish the crop.) A crop that is particularly well suited to mid-season irrigation interruption is alfalfa because, when water is withheld, the crop goes dormant as soil moisture is depleted and resumes growth when irrigation is resumed.

Analysis would focus on the cost and efficiency of generating payback water in this manner.

7.3.2. Incurring Managed Increased Risk to Reservoir Carryover Storage

The objective of paying reservoirs back is to avoid impacts to water supply due to project operations. Analyses to date reveal that re-operated reservoirs frequently recover from surplus surface flows and need to be paid back only infrequently. Given infrequent need for and high cost of reservoir payback, one alternative is simply to deal with the occasional shortages caused by project operations when they occur. Essentially this means passing water supply shortages on to existing CVP and SWP water users. The first step in exploring this option would be to characterize the frequency and magnitude of water supply shortages and then develop strategies for compensating water users accordingly. For example, some users might alternative supplies that could be called on or conservation measures that could be invoked to deal with temporary shortages.

7.3.3. Sharing Private Groundwater Wells

Two options for establishing project groundwater pumping capacity have been explored thus far, including constructing new groundwater production wells and purchasing existing groundwater wells from willing sellers. Both of these are expensive options. The objective of further investigation would be to explore ways to access existing private wells in a manner that avoids the full capital outlay associated with new well construction (or existing well purchase) yet offers reasonably reliable access to payback capacity for project operations, when needed. This would be approached through interviews with landowners to test their willingness and the terms under which they would share production well costs and groundwater supplies with the project.

7.4.South of Delta Groundwater Banking

As previously noted, this investigation was conducted consistent with its original Sacramento Valley focus. Accordingly, reservoir releases made for project environmental purposes were tracked into the Delta but no analyses were performed to estimate whether or to what extent those inflows might be exported from the Delta. The economic analysis did reveal that project economics are dramatically improved if project water supplies could be sold at the higher rates associated with south of Delta water markets compared to Sacramento Valley rates. Beyond higher water sales revenues, banking project water in south of Delta groundwater banks might reduce reliance on Sacramento Valley reservoir payback operations. For example, there may be times when CVP and SWP reservoir releases can be reduced in exchange for water withdrawn from south of Delta groundwater banks. However, this is unlikely to be the case in very dry conditions when reservoir releases are being made exclusively for temperature control and not for export. Operations analyses are needed to reveal whether such opportunities exist.

A major challenge to the analysis will be the current uncertainty in Delta conveyance capacity and operating conventions, presently under consideration in development of the Bay-Delta Conservation Plan.

7.5.Develop System-wide Project Accounting Conventions

The central tenant of the conjunctive operations strategy developed through this project is that existing project beneficiaries can be kept whole while additional environmental flow and water supply benefits are generated. Keeping existing beneficiaries whole requires that an accounting be maintained of project assets, debts and repayment. In the simulations conducted for the project, operational changes (incremental project releases and refill) were isolated in either Shasta or Oroville and therefore easily accounted for. In actual operations, such an explicit accounting would not be practical considering that operations are highly interconnected and effects would likely be distributed among CVP and SWP reservoirs. This point was emphasized by the CVP and SWP project operators.

The purpose of this task would be to identify and evaluate alternative approaches to accounting for the effects of conjunctive operations on reservoir operations throughout the CVP and SWP systems. One approach would be to keep two sets of records, once for actual operations and another set for hypothetical operations as if the project was not operating. This is not considered to be practical or advisable due to the uncertain and, at times, arbitrary nature of maintaining the shadow records. Instead, a more practical approach would be to develop simplified accounting conventions based on simulated project operations.

7.6.Update and Refine Surface Water and Groundwater Models

The surface water and groundwater models developed for this investigation were adequate for planning level analyses but should be refined if further investigations are conducted. The main opportunities for improvements are as follows:

- A preliminary assessment of the accuracy of SACFEM at matching a limited number of historic hydrographs was performed, and the model appears to generally replicate historically observed water levels quite well over the 22-year period of simulation (1982 through 2003). It is recommended that a rigorous transient calibration be conducted of the SACFEM groundwater model to observed historic water level hydrographs across the valley. This effort would help improve the level of confidence that the model is accurately simulating transient patterns in groundwater levels seen historically.

- Another area of potential SACFEM refinement is to further evaluate hydrology of smaller unregulated tributaries across the valley, specifically to better understand timing and magnitude of groundwater recharge that occurs from these surface water features. In the current analysis, it was assumed that unregulated streams were dry from June through October. While this assumption is reasonable, it is likely that behavior of these streams is more complex. Further, some of these tributary streams are used as conveyance facilities to deliver water within various water districts. This would result in streams being active over summer months, and potential sources of recharge to the groundwater system. An analysis of these stream characteristics could improve the accuracy of the simulation of recharge sources to the groundwater system, especially over the summer months.

- Conjunctive management operations as simulated for this investigation may have impacts on the generation and use of CVP and SWP hydropower. For example, in some years, making large reservoir releases for certain environmental objectives may be constrained by power plant capacities and may occur at times when power is less valuable. A better understanding of these constraints and simulation of resulting effects is necessary if further investigation is undertaken.

- Analysis presented in this report focused on operation of only part of the CVP/SWP system. Shasta and Oroville Reservoirs and the Sacramento and Feather Rivers are part of a larger system that is operated in a coordinated manner. Simulation of only part of the system may underestimate benefits or impacts to other areas of the system. Preliminary analysis of systemwide effects based on how conjunctive management operations change, Delta inflows need to be refined and expanded to other areas of the system

Appendices

Appendix A
Materials from October 21, 2010 and December 8, 2010 Public Meetings

October 21, 2010
Public Meeting Materials

Northern Sacramento Valley Conjunctive Water Management Investigation

Public Workshop

Glenn-Colusa Irrigation District Main Pump Station
7854 County Road 203
Hamilton City, California

October 21, 2010

3:00 to 5:00 PM

Workshop Objectives

- Provide a status report on the investigation progress
- Listen/Respond to stakeholder questions
- Describe next steps to investigation, public meetings, and final report

Agenda

1. Welcome, Introductions, Workshop Process
2. Workshop Objectives
3. Recent Regulatory and Legislative Changes and Impacts
4. Investigation Review and Update – Presentation
5. Q&A
6. Regional Water Issues
7. Next Steps
8. Closing

Northern Sacramento Valley Conjunctive Water Management Investigation
Public Meeting
October 21, 2010
GCID Pump Station
Hamilton City, California
Sign in Sheet

PLEASE PRINT

Name	Address	City, State & Zip	Telephone #	e-mail
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Ellen Simon	283 Red Tape Rd	Cherokee	534-0400	—
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[illegible]	2188 Honey Run Rd. Chico	Chico CA	343-8561	

Northern Sacramento Valley Conjunctive Water Management Investigation
Public Meeting
October 21, 2010
GCID Pump Station
Hamilton City, California
Sign in Sheet

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Northern Sacramento Valley Conjunctive Water Management Investigation
Public Meeting
October 21, 2010
GCID Pump Station
Hamilton City, California
Sign in Sheet

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Northern Sacramento Valley Conjunctive Water Management Investigation

Public Meeting
October 21, 2010
GCID Pump Station
Hamilton City, California
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Northern Sacramento Valley Conjunctive Water Management Investigation

The Glenn-Colusa Irrigation District and
The Natural Heritage Institute

October 21, 2010

Today's Workshop Objectives

- Provide a status report on the investigation progress
- Listen/Respond to stakeholder questions
- Describe next steps to investigation, public meetings, and final report

Motivating Factors - Regulatory and Legislative Changes

- Significant Values are at Risk: Regional Sustainability
  - Environmental
  - Water supply
  - Economy
- New Challenges
  - SWRCB Flow Report: 75% unimpaired flow to the Delta November-June
  - DFG Report confirms similar flow needs
  - Delta species (smelt) dominate, salmon at risk
  - Delta Stewardship Council: All Delta all the time
  - Scott Valley/Siskiyou County Groundwater Pumping Lawsuit
- The Past is the past, How do we control our destiny?
- Historical operations and uses are constantly changing
- Local needs and flexibility are now challenged in the Delta context
- Increasing costs and fees
- Long term stability and reliability?

Emerging Values

- What does the region want, what values should be protected?
  - Water supply reliability (surface/groundwater)?
  - Environmental protection/enhancement, both instream and terrestrial?
  - System sustainability, what is it?
  - Others…?
- What strategies should be pursued to achieve regional goals?
  - Status quo?
  - Regional water investigations and planning?
  - Others…?
- Just say no…will that do?

Overview of Investigation to Date

Program Objective

- Examine whether and how operation of groundwater aquifers in the Sacramento Valley could be integrated with operation of existing surface water reservoirs to produce additional firm water supplies
- Potential benefits:
  - Improved water supply reliability (local, regional, State)
  - Ecosystem restoration (Sacramento and Feather Rivers)
  - Improved Delta inflow per BDCP
  - Increased operational flexibility (CVP, SWP, local)
  - Buffer effects of climate change

Program Requirements

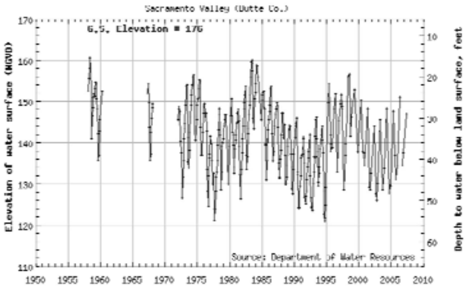
- New net benefits for Sacramento Valley environment and water users
- CVP and SWP commitments honored (to the extent they presently are)
- No unmitigated impacts to existing groundwater users
- Economic feasibility

Initial Site Screening

What Makes for an Attractive __Water Banking__ Site?

- Groundwater conditions
  - Available aquifer storage space
  - Viable recharge mechanism
  - Productive groundwater wells
  - Suitable GW quality
- Surface water conditions
  - Surplus flows at times
  - Connection to CVP, SWP or other surface water reservoirs
  - Dual SW and GW use option
- Impacts/mitigation
  - Isolation from important surface streams
  - Isolation from existing groundwater production wells
  - Ability to mitigate or compensate impacts that cannot be avoided

Typical Sacramento Valley GW Hydrograph (Butte Co.)



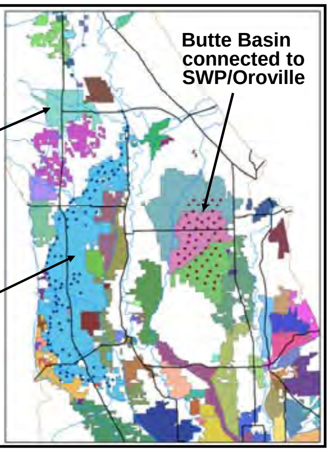
Source: Department of Water Resources

Early Finding: Traditional water banking generally not viable in the Sacramento Valley due to lack of aquifer storage space.

Re-operate Surface Reservoirs with Groundwater "Backstop"

- Reservoir re-operation
  - Additional releases to meet program objectives
  - Hope for reservoir refill from surplus surface flows
  - Honor existing CVP and SWP delivery obligations and operations constraints
- Groundwater operation
  - Pump groundwater to "repay" reservoirs if storage conditions put contract deliveries or temperature control at risk
  - Groundwater used in lieu of surface entitlements that then remain in storage

Three Sites Identified

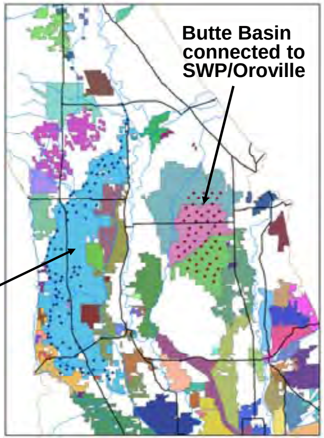


Butte Basin connected to SWP/Oroville

Orland Unit connected to Stony Creek Reservoirs

Glenn-Colusa ID connected to CVP/Shasta

Two Sites Selected for Modeling



Butte Basin connected to SWP/Oroville

Glenn-Colusa ID connected to CVP/Shasta

Re-operation Conceptual Example

- Release water from CVP and/or SWP reservoirs to meet project objectives:
  - Unmet local ag demands
  - Regional environmental flow targets
- <u>If reservoirs refill</u>, no subsequent GW pumping is needed
- <u>If reservoirs do not refill</u>, pump GW and forego use of surface water in following year as needed for reservoir "payback"
- New SW supplies can be generated with infrequent additional GW pumping, because reservoirs refill most years

Project Scenarios Defined by Groundwater Pumping Capacity and Season

Scenario	Groundwater Pumping Capacity (thousand acre-feet)			Pumping Season
	GCID (CVP)	Butte Basin (SWP)	Total	
1	100	50	150	summer
2	200	100	300	summer
3	100	50	150	fall
4	100	50	150	summer & fall

All scenarios modeled with an existing (shallow) and new (deep) well field to reveal range of potential impacts to streams and existing pumpers.

Surface Water Model Results

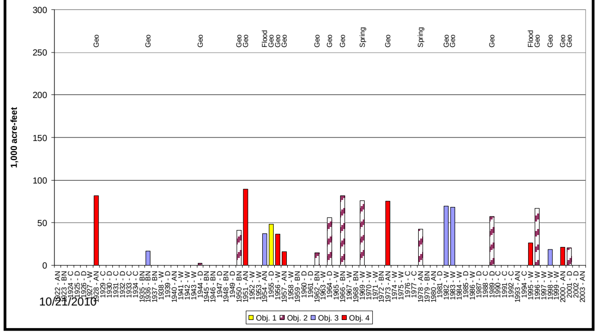
(Example for Scenario 1, Shasta/CVP, 100 TAF Pumping Capacity in GCID)

- Environmental flow releases
- Agricultural deliveries
- Refill from surplus surface water
- Refill from groundwater pumping

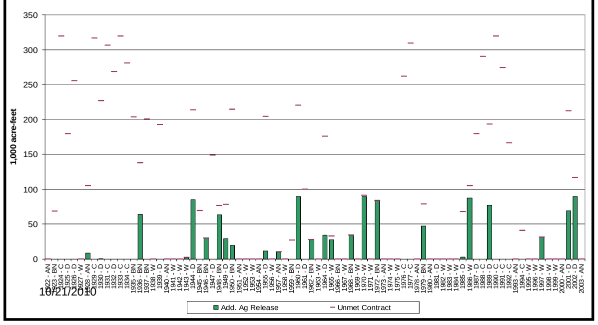
Environmental Flow Objectives

- Geomorphic
  - Single day large event
  - February or March
- Riparian establishment
  - Five day large flow with 60 day recession
  - April start
- Flood plain inundation
  - Single day large event with 45 day recession
  - Between February and April
- Spring pulse flow
  - Simulate more natural spring runoff period

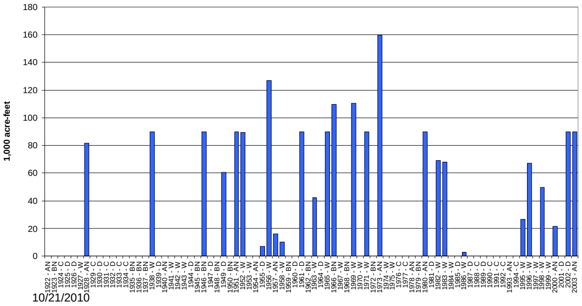
Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Environmental Flow Releases



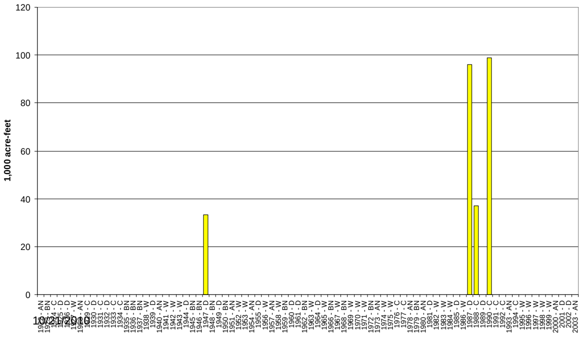
Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Sac River Agricultural Deliveries



Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Refill from Surplus Surface Water



Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Refill from Groundwater Pumping



SW Modeling Summary
(Annual averages 1922-2003, taf)

Scenario	CVP/Sacramento River				SWP/Feather River			
	Env. Rel.	Ag. Del.	Refill from SW	GW Pump	Env. Rel.	Ag. Del.	Refill from SW	GW Pump
1,3 and 4	13	14	24	3	7	10	14	3
2	45	22	58	9	23	20	36	7

SW Modeling Summary
(Average in years of occurrence 1922-2003, taf)

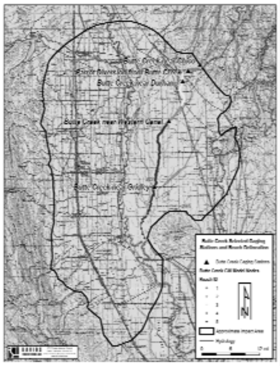
Scenario	CVP/Sacramento River				SWP/Feather River			
	Env. Rel.	Ag. Del.	Refill from SW	GW Pump	Env. Rel.	Ag. Del.	Refill from SW	GW Pump
1,3 and 4	94	46	70	70	49	27	32	44
2	187	75	139	123	95	52	72	75

Project Impacts Due to Additional Groundwater Pumping

- Streamflow
  - Butte Creek in affected area
  - Other critical streams not in affected areas
  - Ephemeral streams not analyzed
- Groundwater levels and existing wells
  - Well yield impacts
  - Incremental pumping costs (due to additional lift)

Butte Creek Impacts

- Develop baseline flow from available gauging stations
- Synthesize "with-project" flows based on cumulative reductions in streamflow from changes in stream leakance from GW model



Butte Creek Impacts

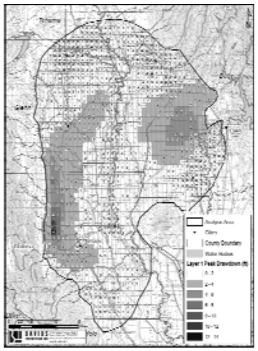
- No impact in upper reaches (primary spawning and holding areas)
- Greatest flow reduction in Jan. – Mar.
  - During times of highest discharge
- Greatest % reduction in summer/early fall
  - Spring-run have already migrated
  - Steelhead just beginning to enter stream
- Rarely drops below in-stream standards
  - June during early '90s drought
- Tradeoffs between Butte Creek impacts and main stem benefits

Impacts to Existing Wells

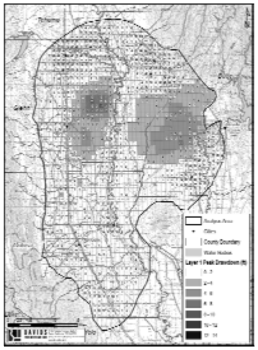
- Used DWR well inventory data
- No appreciable impact on irrigation well performance
  - Increased pumping costs accounted for
- Some impact on non-irrigation wells
  - 9,000 non-irrigation wells in analysis area
  - Up to ~800 non-irrigation wells in impact zones
  - Maximum of 25 (0.2%) to 284 (3%) of wells needing deepening or replacement

Groundwater Levels and Impacts to Wells

Potential Impact Zones:
Worst Case, New Wells



Potential Impact Zones:
Worst Case, Existing Wells



Incremental Pumping Costs

Summary Statistics of Interference Drawdown by Pumping Scenario

	Interference Drawdown (ft)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 kaf Summer Pumping, New Well Field	0.0	13.6	0.5	0.3	0.7
300 kaf Summer Pumping, Existing Well Field	0.0	8.3	0.4	0.2	0.6
150 kaf Summer Pumping, New Well Field	0.0	6.2	0.3	0.2	0.4
150 kaf Summer Pumping, Existing Well Field	0.0	5.4	0.3	0.2	0.4
150 kaf Fall Pumping, New Well Field	0.0	7.0	0.4	0.2	0.4
150 kaf Fall Pumping, New Well Field	0.0	6.1	0.4	0.2	0.5
150 kaf Summer & Fall Pumping, New Well Field	0.0	5.9	0.4	0.2	0.4
150 kaf Summer & Fall Pumping, New Well Field	0.0	5.0	0.4	0.2	0.5

Incremental Pumping Costs

Summary Statistics of Total Increased Annual Energy Costs to Maintain Existing Groundwater Pumping for Irrigation.

	Increased Annual Energy Cost (Total $)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	$65,770	$705,326	$228,397	$168,480	$177,411
300 TAF Summer Pumping, Existing Well Field	$60,110	$497,233	$194,859	$154,452	$140,481
150 TAF Summer Pumping, New Well Field	$37,538	$377,222	$139,402	$104,710	$ 94,209
150 TAF Summer Pumping, Existing Well Field	$39,866	$367,467	$148,075	$126,209	$ 97,078
150 TAF Fall Pumping, New Well Field	$10,993	$344,156	$122,601	$124,133	$ 80,913
150 TAF Fall Pumping, Existing Well Field	$10,292	$401,570	$138,222	$134,018	$ 95,827
150 TAF Summer & Fall Pumping, New Well Field	$44,736	$294,296	$140,169	$120,727	$ 81,830
150 TAF Summer & Fall Pumping, Existing Well Field	$47,471	$345,330	$151,533	$132,451	$ 91,202

(Incremental costs for non-irrigation pumping on the order of $3000 - $5000 per year depending on pumping scenario)

Benefit-Cost Summary

All present values in million dollars [2009]

Scenario				
No.	**Description**	**Benefits**	**Costs**	**Benefit – Cost**
1	150 TAF Summer, New Wells	73	135	-62
1	150 TAF Summer, Existing Wells	73	94	-21
2	300TAF Summer, New Wells	183	290	-107
2	300 TAF Summer, Existing Wells	183	212	-29
3	150 TAF Fall, New Wells	74	210	-136
3	150 TAF Fall, Existing Wells	74	144	-70
4	150 TAF Summer & Fall, New Wells	73	88	-15
4	150 TAF Summer & Fall, Existing Wells	73	65	8

Latest Activities and Findings

Exploring Operations for Additional Environmental Benefits

- Consultation with CVP and SWP operators
- Complying with temperature requirements of greatest concern
  - Operators provided “unofficial” operations criteria for modeling
- Operating for temperature benefit involves tradeoffs with project environmental flow objectives

Temporary Crop Idling to Reduce Payback Cost

- Investigated crop idling as an alternative to GW pumping for reservoir payback
  - Voluntary, incentive driven
- Less cost-effective than pumping due to:
  - High cost: crop idling decisions have to be made early before hydrologic conditions are known
  - Marginal effectiveness: not all of the avoided water use results in reservoir payback

Principal Findings to Date

- SWP and CVP operational requirements are complex and constraining
  - Must honor all Project commitments and operations rules
  - Cold water pool management has dominant effect
- Cost of payback water is appreciable
  - Groundwater pumping
  - Temporary crop idling
- Project cost-effectiveness is marginal
  - Use of Sac groundwater to “backstop” entails mitigation costs
  - Project water produced in wetter years because it cannot be banked
  - Modest value of water in Sac Valley

Concluding Phase 1

Final Phase 1 Steps

- Technical
  - Frame existing operational constraints and tradeoffs
  - Formulate and model best performing scenario under existing conditions
  - Analyze impacts and economics
- Final Report: draft, final
- Public meetings (between draft and final)
- Scope Phase 2 of Investigation
- Continue regional dialogue

Question & Answer

Discussion

Northern Sacramento Valley Conjunctive Water Management Investigation
Conjunctive Water Management Investigation
Public Workshop
Meeting Notes
October 21, 2010

Present:
Thad Bettner, General Manager, GCID
Grant Davids, Davids Engineering
John Clerici, Outreach Communications Specialist
Gregory Thomas, President, Natural Heritage Institute
Walter Bourez, MBK Engineers
Lee Bergfield, MBK Engineers
Cynthia F. Davis, Director of Communications, GCID
Laurie Merrill Murray, Executive Assistant, GCID

Thad Bettner, General Manager, Glenn-Colusa Irrigation District, welcomed the attendee's and introduced consultant John Clerici, outreach communications specialist, Grant Davids of Davids Engineering, Gregory Thomas, President of Natural Heritage Institute, Walter Bourez, MBK Engineers, and Lee Bergfield, MBK Engineers.

Mr. John Clerici called the public meeting to order at 3 p.m. and explained ground rules for participation during the meeting. Approximately 50 members of the public attended (see sign-in sheet).

Mr. Bettner reported that there is currently a significant risk for water in the north state. The State Water Resources Control Board released a flow report that calls for the current state of the Delta. The report recommends that 75% of all runoff goes to the Delta, and farmers in the Sacramento Valley cannot rely on a 25% supply. The Delta Stewardship Council – all the Delta – all the time. The Council is looking upstream for fixes to the Delta. Scott Valley – Siskiyou County groundwater historical operations are changing. New rules will be set up to serve the Delta. Water supply reliability. Change is upon us, outside factors are upon us.

Grant Davids presented a PowerPoint presentation, and provided information on the investigation covering the last four years. Examined how operation of aquifers in the Sacramento Valley environmental and water users. CVP and SWP have commitments to honor.

The following are general categories (in bold) of interest with some specific comments/questions as examples.

Voracity and specificity with the technical tools used to perform the evaluation.

Some commenters asserted that more detail was required in the areas of the economic analysis such as the value assigned to the groundwater, impacts to specific segments of the agricultural community, etc.

One person asked if the time-step used to develop the groundwater model (monthly) didn't miss some spatial or temporal peculiarities associated with a specific location.

Would like to see more sophistication in terms of groundwater, particularly as it relates to permanent crops/orchards.

Why no critical dry years used in the analysis?

One lady questioned the impacts of groundwater pumping in the valley and its impacts on foothill aquifers. I assume she is confusing the Tuscan Formation and the Lower Tuscan aquifer.

Impacts as described in the investigation.

One foot impact to Big Chico Creek is a big deal in the summer.

What is the extent of the impact on domestic (and other wells)? You show 0 to 6 feet, but you also say that near the wells that are pumping payback water it could be 50 or 60 feet? Even a few feet can have a large impact. This needs to be clarified.

What are the critical recharge months in the upper reaches? In the area in general?

How the project works.

Frequency and severity of payback vs the benefits.

What are the benefits? This was a particular challenge for the Feather River folks. Some examples might help.

How will the reservoir releases be measured? When will we know that water needs to be repaid (what triggers payback)? How does the payback water get used?

Which aquifer are we talking about (deep or surface)? Does this study (can this study) be expanded to show the total groundwater picture?

Where does the water for environmental enhancements come from?

Do commitments still exist if Delta mandates are imposed?

Real project drivers.

Why are we here? There were water rights hearings before (she mentioned NHI but I did not get it all). The elephant in the room is junior water rights holders south of the Delta that are trying to get at our water. We need to save this area?

Land use and cropping decisions in the San Joaquin Valley were also sighted, as well as local growth concerns.

Water transfers and GCID's role in them. How do they benefit the region?

Desire to be part of the discussion.

More meetings to work out the information with the public. Time of day and location, and more focused in terms of subject matter.

There are a lot of resources available from the local groups and individuals. We can help but you need to talk to us more proactively.

Many of these questions do not have clear answers, or are not answerable within the context of the investigation. Some of them like wanting more specific economic analysis or reducing the time-step on the model may either be impractical, or are better left to the more extensive environmental analysis required a the project level.
However providing concrete answers when they are available, as well as providing more detail around how an example project might function, its benefits and impacts, can only help to improve stakeholder understanding of what we have in mind.

I have some thoughts about how we can structure our response but would like to hear what the team has to say before discussing them further.

These are the questions and comments from the 10-21 workshop as I wrote them down. Some appear in the text above as well.

How does this relate to the planning process (city and county general plans)?

Why no critical dry years used in analysis? Doesn't make sense.

The information is going to be used and not used appropriately. There seems to be a lot of pumping.

Confused about the water storage issue. Growth and demand is south of delta which is where he water would seem to go. There is a great deal of risk and uncertainty with what you are doing.

Where does the water for environmental enhancements come from (surface or groundwater)?

Which aquifer are we talking about (deep or surface)? Does this study (can this study) be expanded to show the total groundwater picture?

What's the local/regional share of the 2.5 million af groundwater pumping figure? Need to be more specific.

What is the time step on the groundwater model? We notice changes weekly and even daily based on pumping. May not be reflected in the model.

Explain how there can be no impact in upper reaches of creeks? Does valley pumping impact aquifers in foothills (they think so)? Does the Tuscan aquifer extend into the foothills (Tuscan Formation vs Tuscan Aquifer?)

What are the critical recharge months in the upper reaches? In the area in general?

Seems like more detailed investigation needed to determine impacts of valley pumping on upper reaches.

What is the extent of the impact on domestic (and other wells)? You show 0 to 6 feet, but you also say that near the wells that are pumping payback water it could be 50 or 60 feet? Even a few feet can have a large impact. This needs to be clarified.

Payback issue needs to be explained. How does it work? Accounting?

1 foot of drop in local streams (Big Chico) are significant. Team needs perspective on this.

There are a lot of resources available from the local groups and individuals. We can help but you need to talk to us more proactively.

What is meant by “marginal impacts” at Butte Creek?

What if you end up pumping more than you expect (as a response to prolonged drought)?

Why are we here? There were water rights hearings before (she mentioned NHI but I did not get it all). The elephant in the room is Junior water rights holders south of the Delta that are trying to get at our water. We need to save this area?

Needs more community meetings, but thinks this effort might harm the area. Mentioned drought water bank.

Did you assign any value to the water in the aquifer?

Impacts of local land use decisions need to be taken in account? Have they been?

Explain the externalities in the economic impacts evaluation.

Public wants assurance that there is adequate thought going into monitoring and mitigation.

Can you do just reservoir re-operation without doing the pumping for repayment?

Do commitments still exist if Delta mandates are imposed?

What are the existing contractual obligations?

Would like to see more sophistication in terms of groundwater, particularly as it relates to permanent crops/orchards.

Clarification requested on groundwater and surface water.

Models are tools – assign value to aquifer. Add to next agenda.

December 8, 2010
Public Meeting Materials

Northern Sacramento Valley
Conjunctive Water Management Investigation

Public Workshop

Masonic Lodge
1110 W. East Avenue
Chico, CA 95926

December 8, 2010

6:00 to 8:00 PM

Workshop Objectives

- Respond to questions from October 21, 2010 workshop

Agenda

1. Welcome, Introductions, Workshop Process
2. Discuss questions from 10-21 Workshop
   a. How does the proposed project work?
   b. Investigation Tools and Data
   c. Project Benefits
   d. Project Impacts
3. Next Steps/Closing

Public Workshop

Northern Sacramento Valley Conjunctive Water Management Investigation

December 8, 2010

6:00 p.m. – 8:00 p.m.

Masonic Lodge
1110 W. East Avenue
Chico, CA 95926

The Glenn-Colusa Irrigation District (GCID) and the Natural Heritage Institute (NHI) are in the process of evaluating water management opportunities in the northern Sacramento Valley. This effort, the Northern Sacramento Valley Conjunctive Water Management Investigation (Investigation), is nearing completion of several years of work with a draft final report currently under preparation.

This workshop is being sponsored specifically to provide responses to the questions and comments received at the Investigation workshop held on October 21, 2010. Topics to be addressed include potential project benefits and impacts, conjunctive operations concepts, project economics, and other issues brought up at the previous session. Time will be allowed for the public to engage in a discussion of the questions and answers and relevant issues related to the Investigation.

Northern Sacramento Valley
Conjunctive Water Management Investigation

Public Workshop

December 8, 2010

Background

On October 21, 2010, the Glenn-Colusa Irrigation District (GCID) and Natural Heritage Institute (NHI) held a public workshop to provide a status report on their Northern Sacramento Valley Conjunctive Water Management Investigation. Meeting participants were also provided an opportunity to ask questions of the investigation team.

As a result of the significant number of questions and comments provided by attendees, GCID and NHI agreed to hold a follow-up workshop. The purpose of the workshop is two-fold: to either respond to questions that could not be addressed at the last meeting, or provide clarification to questions that were answered but warranted additional follow-up; and, to allow for more substantive dialogue between the investigation team and stakeholders on these issues.

Organizing Questions

Questions and comments from the October workshop varied widely but seemed to be focused in four critical areas:

1. Project Operations (How does the proposed project work?)
2. Investigation Tools and Data
3. Project Benefits
4. Project Impacts

These four categories were used to develop the format for today's workshop. For discussion purposes, and to facilitate providing responses, comments were put into the form of a question, and multiple questions of similar nature were consolidated into a single question. Additionally, the technical team assessed which questions could be answered within the context of the current investigation, and which questions either cannot be resolved by this phase of the investigation, or required a venue more suited to a longer-term regional dialogue. The majority of questions fell into the first group and will be responded to in this workshop.

Questions by Category

Project Operations (How does the proposed project work?)

- Can you do just reservoir re-operation without doing the pumping for repayment?
- Where does the water for environmental enhancements and other project benefits come from?
- How does the payback water get used?
- How do the project benefits compare to the frequency and magnitude of payback?
- How would the reservoir releases be measured?
- How would it be determined that water needs to be repaid…what triggers reservoir payback?
- Which aquifer are we talking about, the deep or shallow?
- Does the study address the total groundwater picture?
- What are the existing contractual obligations?
- Public wants assurance that there is adequate thought going into monitoring and mitigation.

Investigation Tools

- Why are critical dry years not used in the analysis?
- What is the time-step used to develop the groundwater model? Is the time-step appropriate for capturing localized effects of day to day well operation and aquifer response?
- Were economic impacts beyond just project costs and benefits considered, such as impacts to specific segments of the agricultural community?

Project Benefits

- What are the project benefits?
- Are there benefits to the groundwater systems and were they considered in the economic analysis?

Project Impacts

- What are the impacts of groundwater pumping in the valley on foothill aquifers?
- What are the critical recharge months in the upper reaches? In the area in general?
- Project pumping may be a small share of Valley wide pumping but what proportion is it of pumping within the project area?
- Is the interconnection between streams and underlying aquifers sufficiently defined to predict the effects of even modest changes in groundwater levels (e.g., Butte and Big Chico Creeks)?
- What is the extent of the impact on domestic (and other wells)? You show 0 to 6 feet, but you also say that near the wells that are pumping payback water it could be 50 or 60 feet? Even a few feet can have a large impact. This needs to be clarified.

Northern Sacramento Valley Conjunctive Water Management Investigation
Public Meeting
December 8, 2010
Masonic Lodge
Chico, California
Sign in Sheet

PLEASE PRINT

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Northern Sacramento Valley Conjunctive Water Management Investigation
Public Meeting
December 8, 2010
Masonic Lodge
Chico, California
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Northern Sacramento Valley Conjunctive Water Management Investigation
Public Meeting
December 8, 2010
Masonic Lodge
Chico, California
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Northern Sacramento Valley Conjunctive Water Management Investigation

Public Workshop

December 8, 2010

The Glenn-Colusa Irrigation District and
The Natural Heritage Institute

Workshop Objective & Process

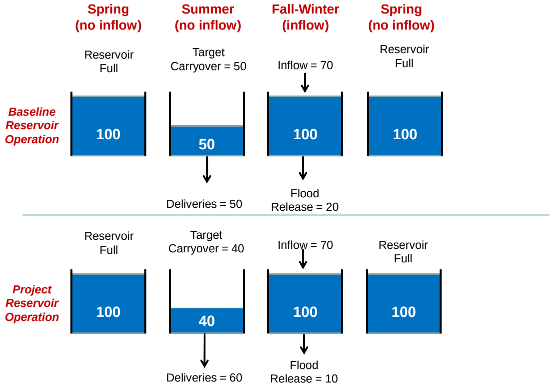
- Objective
  - – Respond to questions from October 21, 2010 workshop 1
- Process
  - – Organized questions into topics
  - – Describe each topic
  - – Provide response
  - – Engage in discussion

How Does The Proposed Project Work?

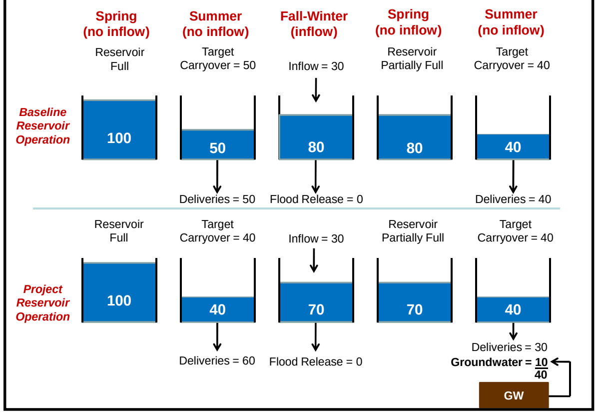
Re-operate Surface Reservoirs with Groundwater "Backstop"

- Reservoir re-operation
  - – Additional releases to meet program objectives (North of Delta water supply and environmental enhancement)
  - – Expect reservoir refill from surplus surface flows
  - – Honor existing CVP and SWP delivery obligations and operations constraints
- Groundwater operation
  - – Pump groundwater to "repay" reservoirs if storage conditions put contract deliveries or temperature control at risk
  - – Groundwater used in lieu of surface entitlements that then remain in storage
  - – Minimize or avoid GW impacts

Re-Operation Case 1- Reservoir Refills



Re-operation Case 2- Reservoir <u>Does Not</u> Refill



Project Performance Summary

Project Scenario 2 Evaluated with Revised Model Including Biological Opinions, Forecast-based Operation and Minimum Reservoir Release Criteria

Performance Metric	Sac R (Shasta)	Feather R (Oroville)
Total number of years in simulation (1922-2003)	82	82
Number of years no project releases made	62	45
Number of years project releases made	20	37
Average annual (82 years) project release, (TAF) (Roughly 2/3 environmental and 1/3 ag benefits) **Cumulative benefit over 82 years (TAF) =**	25 **2,050**	30 **2,460**
Maximum year project release (TAF) (Includes environmental and ag)	180	102
Number of years "payback" pumping is needed	4	11
Average annual (82 years) project pumping (TAF) **Cumulative pumping over 82 years (TAF) =**	2 **164**	9 **738**
Maximum year project pumping (TAF) (Maximums do not occur in same year)	100	100
Average annual (82 years) reservoir refill from surplus flows (TAF)	23	23
Spillage of payback water	0	-2

Questions

How Does The Proposed Project Work?

- Can you do just reservoir re-operation without doing the pumping for repayment?
- Where does the water for environmental enhancements and other project benefits come from?
- How does the payback water get used?
- How do the project benefits compare to the frequency and magnitude of payback?

Questions, continued

How Does The Proposed Project Work?

- How would the reservoir releases be measured?
- How would it be determined that water needs to be repaid…what triggers reservoir payback?
- Which aquifer are we talking about, the deep or shallow?
- Does the study address the total groundwater picture?

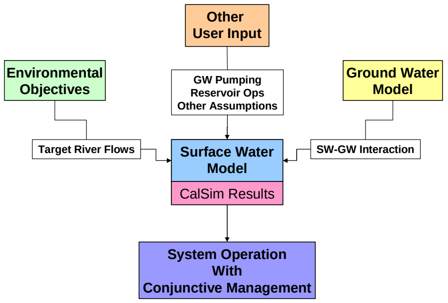
Questions, continued

How Does The Proposed Project Work?

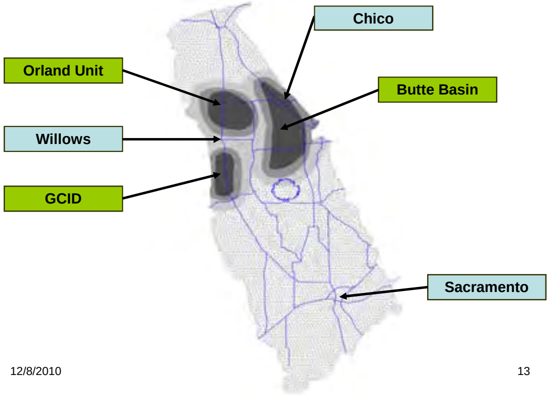
- What are the existing contractual obligations?
- Public wants assurance that there is adequate thought going into monitoring and mitigation.

Investigation Tools and Data

Overview of Analysis Tools



Groundwater Model Area and Grid Density



Groundwater Flow Model

- Regional scale with high spatial detail
  - – 5,950 square miles (3.8 million acres)
  - – 88,922 surface nodes
  - – 7 vertical layers
- Aquifer properties based on analysis of more than 1,000 production wells
- Calibration
  - – Static calibration for year 2000
  - – Water levels from 257 monitoring wells
- Monthly time step, 1982 through 2003

Surface Water Operations Model

- Spreadsheet-based for ease and speed of operation
- Re-operates Shasta and Oroville Reservoirs relative to a baseline condition depicted by CalSim II outputs (1922 through 2003)
- Driven by additional target deliveries for:
  - – Environmental restoration in Sac and Feather Rivers
  - – Unmet Sac Valley agricultural demands
- Various operational constraints
- Uses generalized SW-GW interaction functions derived from GW model

Questions

Investigation Tools and Data

- Why are critical dry years not used in the analysis?
- What is the time-step used to develop the groundwater model? Is the time-step appropriate for capturing localized effects of day to day well operation and aquifer response?
- Were economic impacts beyond just project costs and benefits considered, such as impacts to specific segments of the agricultural community?

Project Benefits

Questions

Project Benefits

- What are the project benefits?
- Are there benefits to the groundwater systems and were they considered in the economic analysis?

Project Benefits

- Increased Sac Valley surface water supply
  - More local benefit (water supply) from CVP and SWP
  - Reduced overall reliance on Sac Valley groundwater, though increased local pumping in certain years
- Improved habitat in Sac and Feather Rivers through
  - Recovery of salmon populations
  - Ecosystem sustainability

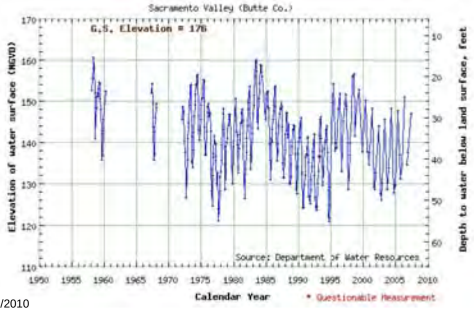
Project Impacts

Questions

Project Impacts

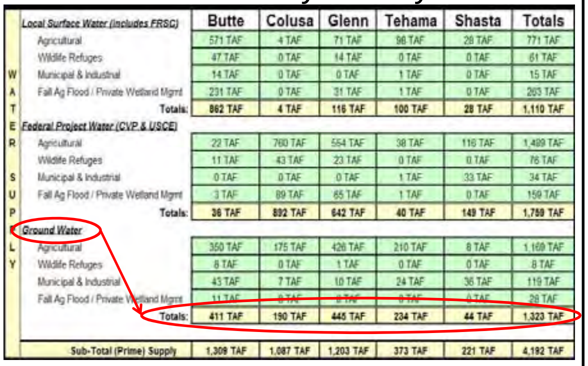
- What are the impacts of groundwater pumping in the valley on foothill aquifers?
- What are the critical recharge months in the upper reaches? In the area in general?
- Project pumping may be a small share of Valley wide pumping but what proportion is it of pumping within the project area?

Typical Sacramento Valley GW Hydrograph (Butte Co.)



Source: Department of Water Resources

Sacramento Valley Water Uses and Sources by County



WATER SUPPLY

	Butte	Colusa	Glenn	Tehama	Shasta	Totals
Local Surface Water (includes FRSC)						
Agricultural	571 TAF	4 TAF	71 TAF	98 TAF	28 TAF	771 TAF
Wildlife Refuges	47 TAF	0 TAF	14 TAF	0 TAF	0 TAF	61 TAF
Municipal & Industrial	14 TAF	0 TAF	0 TAF	1 TAF	0 TAF	15 TAF
Fall Ag Flood / Private Wetland Mgmt	231 TAF	0 TAF	31 TAF	1 TAF	0 TAF	263 TAF
Totals:	**862 TAF**	**4 TAF**	**116 TAF**	**100 TAF**	**28 TAF**	**1,110 TAF**
Federal Project Water (CVP & USCE)						
Agricultural	22 TAF	760 TAF	554 TAF	38 TAF	116 TAF	1,489 TAF
Wildlife Refuges	11 TAF	43 TAF	23 TAF	0 TAF	0 TAF	76 TAF
Municipal & Industrial	0 TAF	0 TAF	0 TAF	1 TAF	33 TAF	34 TAF
Fall Ag Flood / Private Wetland Mgmt	3 TAF	89 TAF	65 TAF	1 TAF	0 TAF	159 TAF
Totals:	**36 TAF**	**892 TAF**	**642 TAF**	**40 TAF**	**149 TAF**	**1,759 TAF**
Ground Water						
Agricultural	350 TAF	175 TAF	426 TAF	210 TAF	8 TAF	1,169 TAF
Wildlife Refuges	8 TAF	0 TAF	1 TAF	0 TAF	0 TAF	8 TAF
Municipal & Industrial	43 TAF	7 TAF	10 TAF	24 TAF	36 TAF	119 TAF
Fall Ag Flood / Private Wetland Mgmt	11 TAF	8 TAF	8 TAF	0 TAF	0 TAF	28 TAF
Totals:	**411 TAF**	**190 TAF**	**445 TAF**	**234 TAF**	**44 TAF**	**1,323 TAF**
Sub-Total (Prime) Supply	**1,309 TAF**	**1,087 TAF**	**1,203 TAF**	**373 TAF**	**221 TAF**	**4,192 TAF**

Peak Year Project Pumping (100 TAF[1]) in Relation to Estimated Annual Baseline Pumping

Area	Estimated Baseline Pumping (TAF)	Project Pumping as % of Area Baseline
Butte County	411	24%
Glenn and Colusa Counties	635	16%
Butte, Glenn and Colusa Counties	1,046	10%
Northern Sacramento Valley (Butte, Glenn, Colusa, Tehama and Shasta Counties)	1,323	8%
Entire Sacramento Valley (Source: GW model water budgets)	2,500 +/-	4%

[1] Peak year project pumping is 100 TAF in the Butte Basin and in GCID but the two not occur in the same year based on the 1922 through 2003 modeling

Questions

Project Impacts

- Is the interconnection between streams and underlying aquifers sufficiently defined to predict the effects of even modest changes in groundwater levels (e.g., Butte and Big Chico Creeks)?

Questions, continued

Project Impacts

- What is the extent of the impact on domestic (and other wells)? You show 0 to 6 feet, but you also say that near the wells that are pumping payback water it could be 50 or 60 feet? Even a few feet can have a large impact. This needs to be clarified.

Comparison of Drawdown from Modeling and Averaged for Impact Analysis

Potential Impact Zones:
Worst Case, New Wells

Regional Aquifer Drawdown in Aug 1990 , Scenario 1, New Well Field

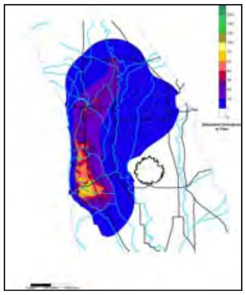


Figure 11-15, p.11-16 from Modeling Report, Feb 2010

Next Steps

- Draft and Final Investigation Report
- Additional public meetings
- Phase 2

Appendix B
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report
MBK/CH2M HILL

Report

Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Prepared for

Glenn Colusa Irrigation District
and the Natural Heritage Institute

February 2010

CH2MHILL
2525 Airpark Drive
Redding, CA 96001

MBK Engineers
1771 Tribute Road
Suite A
Sacramento, CA 95815

Preface

This report was prepared by CH2M HILL and MBK Engineers for Glenn Colusa Irrigation District (GCID) and the Natural Heritage Institute (NHI).The report documents technical analyses conducted to examine potential future coordinated operation of Sacramento Valley groundwater aquifers with California's State Water Project and the federal Central Valley Project. The work was enabled by state and federal grant funds.

Principal investigators were Peter Lawson of CH2M HILL and Walter Bourez and Lee Bergfeld of MBK Engineers. Program management and technical oversight were provided by Grant Davids of Davids Engineering on behalf of GCID and NHI.

Any questions regarding the information presented in this report should be addressed to GCID, NHI, or Davids Engineering.

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Contents, Continued

Appendix A – CalSim II Common Assumptions

Tables

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Figures

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Contents, Continued

Contents, Continued

Contents, Continued

Acronyms and Abbreviations

ac-ft	acre-feet
bgs	below ground surface
cfs	cubic feet per second
CVP	Central Valley Project
Delta	Sacramento-San Joaquin River Delta
DEM	Digital Elevation Model
DWR	California Department of Water Resources
GCID	Glenn Colusa Irrigation District
GIS	geographic information system
gpd	gallon per day
gpm	gallon per minute
NHI	Natural Heritage Institute
OCAP	Operations Criteria and Plan
Reclamation	Bureau of Reclamation
RMS	root mean square error
SACFEM	Sacramento Valley Groundwater Model
Sacramento River Index	Sacramento River Water Year Type Index
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TCCA	Tehama-Colusa Canal Authority

Executive Summary

Project Description

Glenn Colusa Irrigation District (GCID) and the Natural Heritage Institute (NHI) are conducting an analysis of conjunctive management opportunities in the Sacramento Valley (Project). The purpose is to examine whether and how groundwater production from the Lower Tuscan Aquifer and related deep aquifers in the Sacramento Valley can be integrated with the operations of existing surface water reservoirs to produce additional water to satisfy unmet agricultural demands in the Valley (preferentially), or south of the Sacramento-San Joaquin River Delta (Delta). A secondary objective is to evaluate the potential to increase the operational flexibility of these reservoirs so that they can contribute to meeting environmental flow targets in the Sacramento and Feather Rivers.

Technical Analysis

The Project includes conducting planning-level technical analyses and modeling of the following:

- How conjunctive management projects may operate
- How additional water supplies may be developed
- How reservoirs can be reoperated to generate environmentally beneficial flow patterns
- What effects the Project could have on both the surface and groundwater systems in the Sacramento Valley.

This report documents the development of the surface water and groundwater modeling tools used in the analysis, the assumptions made during the development process, and presents results of the modeling analyses.

Technical analysis was performed using two models: one for the surface water system and one for the groundwater system. The surface water model was developed to analyze operations of conjunctive management projects, reservoir operations, environmental objectives, and agricultural water demands quickly for a variety of different project, operations, and objectives. The surface water model was used in gaming sessions and by members of the project team to understand benefits, risks, and limitations of various conjunctive management configurations.

A regional groundwater model was also developed to simulate the effects of conjunctive management operations on the aquifer system with a spatial resolution at project sites capable of evaluating effects on a well field scale. The groundwater model was used to investigate differences in aquifer drawdown and changes in stream-aquifer interaction for different pumping capacities, seasons, and well field configurations.

The two models were used in an interactive fashion to simulate project operations and better understand the interactions between the surface water and groundwater systems. The surface water model was used to determine timing and quantity of conjunctive management pumping. Pumping time series were then simulated in the groundwater model and changes in stream-aquifer interactions were input back into the surface water model to understand how those changes might affect system operations.

Technical analyses were performed at a planning level to help prove concepts and define potential conjunctive management configurations and operations. Analyses were conducted for general projects, locations, and operations. More specific and refined analysis will be required as specific projects are defined. Most of the analyses contained herein were conducted in a comparative (rather than absolute) manner, and results must be interpreted with this in mind. Comparisons of benefits and impacts between different scenarios or well fields help inform decisions on what projects work better than others.

Projects, Operations, and Scenarios

The project team developed an initial list of nine prospective project sites and screened these down to two project sites for more in-depth analysis and modeling. One project site is located within GCID and is integrated with the Central Valley Project's (CVP) operation of Shasta Reservoir. The second project site is located in Western Canal Water District and Richvale Irrigation District (Butte Basin) and integrated with the State Water Project's (SWP) operation of Oroville Reservoir.

The team used its understanding of annual aquifer drawdown and recovery to develop a conjunctive operation configuration that relies primarily on re-operation of existing reservoirs to achieve the project objectives, drawing on groundwater as a backstop. The term "backstop" refers to the potential to use groundwater supplies on a temporary basis to make up for shortfalls in surface water supplies due to modified operations. Groundwater provides an additional source of water to protect surface water reservoirs from being excessively depleted. This type of operation offers different opportunities and challenges than conventional groundwater banking. Surface water is not banked in the aquifer in wet years and recovered during dry years. Instead, additional water is released from surface reservoirs for delivery to meet Project objectives (unmet local irrigation demands and environmental flow targets). These releases result in lower end-of-year reservoir storage levels and more reservoir space available to capture winter runoff.

The goal of this operation is to develop additional water supply by refilling reservoir space vacated by additional Project releases with captured surplus surface water that otherwise would be released for flood control. In years when refill is not complete, Project pumping produces groundwater for use in Project areas in lieu of surface water deliveries that would otherwise be made from reservoirs. This allows an equivalent volume of water to remain in reservoir storage to recover from prior year project releases.

This mode of conjunctive operation, in which reservoir operation is used as the primary means to develop new water supply and groundwater is used infrequently as a backstop, is highly efficient because it reduces the frequency and volume of groundwater pumping in comparison to conventional groundwater banking operations. Groundwater pumping is relied upon only as needed to maintain reservoir storage when refill from surplus winter flows is insufficient.

In some years, conditions in the Sacramento Valley may be so critically dry that Project pumping would be suspended altogether. For instance, if groundwater levels were already at levels of concern (according to county Basin Management Objectives or other standards), Project wells would be turned off and the Project would generate no new supplies under these conditions.

Project operations were simulated for the four different conjunctive management scenarios summarized in Table ES-1.

TABLE ES-1
Summary of Project Scenarios Evaluated
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Scenario	GCID Annual Pumping Capacity	Butte Basin Annual Pumping Capacity	Pumping Season
1	100 TAF	50 TAF	Summer (May through August)
2	200 TAF	100 TAF	Summer (May through August)
3	100 TAF	50 TAF	Fall (September through November)
4	100 TAF	50 TAF	Summer and Fall (May through November)

TAF = thousand acre-feet

Additionally, pumping for each scenario was evaluated for two different well fields. The first well field simulated pumping from existing wells screened in the current aquifer production zones at depths between 100 and 500 feet. The second well field simulated pumping from new wells screened in the deep aquifers at depths between 900 and 1,100 feet.

Results and Conclusions

Table ES-2 presents a summary of results for each scenario and well field configuration. Water supply results are average annual new water supplies developed to meet project objectives. Groundwater results show only the peak impacts to groundwater levels and streams.

Table ES-2 shows that for the two pumping capacities evaluated, the average annual additional water supply is approximately one third of pumping capacity. Additionally, approximately 85 percent of the new water supply developed comes from capture of surplus surface water with the remaining 15 percent from additional groundwater pumping. Average annual groundwater pumping volumes are the result of infrequent but large pumping quantities up to the total project capacity in a given year.

Surface water operations and the resulting groundwater pumping are primarily driven by reservoir storage levels. Therefore, differences in the season of conjunctive management pumping evaluated with Scenarios 3 and 4 have little effect on water supply. However, the duration of the pumping season has a more significant effect on the magnitude of drawdown produced in the aquifer system, and results in differences in projected stream impacts.

TABLE ES-2
Summary of Results for Each Project Scenario and Well Field Configuration
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Pumping Capacity (TAF)				Source of New Water Supply			Max Local Drawdown[a] (feet)		
Scenario	**GCID**	**Butte Basin**	**Pumping Season**	**New Water Supply[b] (TAF)**	**Surplus Surface Water[b] (TAF)**	**GW Pumping[b] (TAF)**	**Well Field**	**GCID**	**Butte Basin**	**Peak Streamflow Impact[c] (cfs)**
1	100	50	Summer	44	38	6	Existing	30-40	<10	54
							New	~100	10-20	53
2	200	100	Summer	110	94	16	Existing	~100	20-30	111
							New	~200	20-30	105
3	100	50	Fall	44	38	6	Existing	40-50	10-20	80
							New	~125	30-40	90
4	100	50	Summer and Fall	44	38	6	Existing	20-30	<10	64
							New	40-50	10-20	65

[a] Maximum local drawdown is the maximum monthly simulated drawdown within the pumped aquifer for that particular conjunctive management project during the period of simulation

[b] Annual Average

[c] Peak stream impact is the maximum monthly aggregated reduction in stream flow for all streams explicitly simulated in the groundwater model during the period of simulation

Note:

cfs = cubic feet per second

Table ES-2 shows that for a given project production capacity, the greatest drawdown occurs during fall pumping simulations because pumping occurs over 3 months, resulting in higher instantaneous rates. An intermediate magnitude of drawdown is observed for pumping over a 4-month summer period, and the least drawdown is predicted for the 7-month summer/fall pumping period.

Production of groundwater from new wells screened in the deeper aquifer results in greater drawdown than pumping the same quantities at the same rates from existing wells. This is because the pumping from new wells is assumed to occur from the 200-foot thickness that comprises model layer 6 (approximately 900 to 1,100 feet below ground surface ([bgs]), whereas the pumping from existing wells occurs from the approximate 400-foot thickness of the regional aquifer (200 to 600 feet bgs). This greater aquifer thickness provides a significantly greater aquifer transmissivity to provide water to the pumping wells, and therefore less drawdown is simulated for a given pumping rate. Additionally, the new well field for the GCID Project is assumed to be located closer to the low permeability bedrock that borders the western edge of the alluvial aquifer; therefore, less water is available to satisfy pumping demands. These assumptions, combined with the larger pumping volumes, help explain why the differences in drawdown between a new and existing well field are larger in the GCID Project than the Butte Basin Project.

Simulated drawdown near the Butte Basin Project is lower than simulated drawdown near the GCID Project. This is due to a combination of lower overall production rates and a greater production well spacing.

Comparisons of peak streamflow impacts between scenarios show that higher production rates generally result in greater peak impacts with the exception of a comparison between Scenario 1 and 4. Differences in peak stream impacts between Scenarios 1 and 4 can be explained by the timing of when ephemeral streams are simulated to flow in the model. The peak drawdown effects for Scenario 4 were evaluated in November (the end of the production season), when west side ephemeral streams are assumed to be active. These streams provide an additional source of recharge to the aquifer system, resulting in a lesser magnitude of predicted drawdown. This can also be seen in the cumulative peak stream impact, which is greater for Scenario 4 than for Scenario 1.

Lower project pumping rates of Scenarios 1 and 4 predict similar peak stream impacts for new and existing well fields. Moderate production rates in Scenario 3 show greater peak impacts of new wells than those produced by existing wells. At the highest production capacity in Scenario 2 the existing well field produces greater peak impacts to streams than the new well field.

SECTION 1

Introduction and Background

Glenn Colusa Irrigation District (GCID) and the Natural Heritage Institute (NHI) are conducting an analysis of conjunctive management opportunities in the Sacramento Valley (Project). The purpose is to examine whether and how groundwater production from the Lower Tuscan Aquifer and related deep aquifers in the Sacramento Valley can be integrated with the operations of existing surface water reservoirs to produce additional water to satisfy unmet agricultural demands in the Valley (preferentially), or south of the Delta. A secondary objective is to evaluate potential to increase the operational flexibility of these reservoirs so that they can contribute to meeting environmental flow targets in the Sacramento and Feather Rivers.

The Project planning area encompasses the entire Sacramento River basin, although primary attention focuses on areas of the northern Sacramento Valley. This includes portions of Butte, Colusa, Glenn, and Tehama counties. Operational strategies developed do not necessarily depend on the Lower Tuscan and related deep aquifers, or any particular portion of the groundwater system for that matter. The strategies are generally applicable wherever productive aquifers exist regardless of their depth or extent.

The scope of the planning effort includes technical analyses with emphasis on surface water and groundwater modeling to define conjunctive management operations and their benefits and impacts. This report provides specific documentation on modeling tools developed for this analysis, projects and scenarios simulated, and model results. Additionally, the report supports preliminary engineering analyses and development of project cost and benefit estimates to allow for economic evaluation of prospective projects.

Any new groundwater pumping in the Sacramento Valley would have at least temporary effects on groundwater conditions and could affect existing groundwater users and flow in rivers and streams. Therefore a major component of the Project is to address risks to existing water users and streams. Risk management strategies that will be investigated include risk avoidance and minimization, such as locating and designing production wells in ways to isolate impacts, and risk mitigation to compensate for effects that cannot be avoided. An overarching principle of the Project is that existing water users, at a minimum, would not be adversely impacted and preferably will benefit from conjunctive operations.

SECTION 2

Conclusions

2.1 Surface Water System

Conjunctive management in which groundwater pumping capacity is used as a backstop to allow more aggressive operation of surface water reservoirs in the Sacramento Valley may be an efficient method to increase water supply. More aggressive operation of reservoirs produces additional water supply primarily through capture of surplus surface water and to a lesser extent through additional groundwater pumping. Table 2-1 summarizes average annual water supply developed for agricultural and environmental objectives and the source of additional supply, either surplus surface water or groundwater, for the two different project capacities evaluated.

TABLE 2-1
Summary of Average Annual Water Supply Benefits and Source of Additional Supply
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Additional Water Supply (TAF)			**Capture of Surplus Surface Water**	**Additional Groundwater Pumping**
Project Capacity	**Agricultural**	**Environmental**	**Total**		
150 TAF	24	20	44	38	6
300 TAF	42	68	110	94	16

Table 2-1 shows that for the two capacities evaluated, additional water supply is approximately one-third of project groundwater pumping capacity. Additionally, approximately 85 percent of the water supply developed comes from capture of additional surface water with the remaining 15 percent from additional groundwater pumping. Average annual groundwater pumping volumes are the result of infrequent but large pumping quantities up to the total project capacity in a year.

Surface water operations and the resulting groundwater pumping are primarily driven by reservoir storage levels. Therefore the season of conjunctive management pumping whether summer, fall, or summer and fall has only minor operational affects. However, pumping season may have more significant effects on aquifers and current groundwater users.

Additional important conclusions can be drawn from the sensitivity/tradeoff analysis. Projects with larger pumping capacities tend to contribute more toward meeting environmental objectives, while smaller capacity projects contribute more to agricultural objectives for the following two reasons:

- Water costs associated with meeting environmental objectives are typically high and require larger project capacities to meet.
- Environmental objectives were assumed to be all-or-nothing thresholds while any additional water supply could be used to meet agricultural objectives.

These two factors also result in the two objectives being less competitive for additional water supply than may be expected. A different prioritization between the two objectives did not result in a one-for-one tradeoff of benefits.

Tradeoff analysis also provided insight into risks associated with more and less aggressive conjunctive management operations. For the surface water system, these risks are focused on reservoir storage levels and ability to meet contract requirements and temperature control criteria in future years if reservoirs are drawn down too far.

Sensitivity analysis conducted when environmental flow targets were varied demonstrated that for most objectives changes of 10 percent did not erase, or greatly increase, project benefits. Therefore, conjunctive management projects, as defined in this study, could likely be used to meet environmental objectives, even with the uncertainty inherent in flow targets and real-time operations.

Conjunctive management operations within the Sacramento Valley may make additional water supply available south of Delta if reservoir releases to meet environmental objectives can be exported. There exists some ability to export these releases when not considering export restrictions for the protection of Delta smelt. However, export restrictions as proposed in the recently release Operations Criteria and Plan (OCAP) Biological Opinion likely reduce or eliminate this potential benefit.

2.2 Groundwater System

The eight simulations described in this study were designed to test four different project scenarios while holding remaining variables constant. Parameters evaluated in the four scenarios included quantity of groundwater pumped, duration of production (which influences production rate), seasonality of production, and spacing and location of production well fields, including proximity to surface streams. Conclusions are divided into those regarding groundwater level effects followed by those regarding effects on surface water flows. Drawdown estimates provided are regional drawdown estimates. The magnitude of local drawdown adjacent to individual production wells will be significantly greater.

2.2.1 Groundwater Levels

Production of 150 TAF of groundwater from existing wells over the summer (May through August) results in a maximum drawdown of approximately 40 feet in the pumped aquifer, whereas production of 300 TAF of groundwater results in a maximum of approximately 75 feet of drawdown.

Production of 150 TAF of groundwater from new deeper wells over the same months results in a maximum of approximately 75 feet of drawdown in the pumped aquifer, whereas the production of 300 TAF of groundwater results in approximately 150 feet of drawdown.

Production of 150 TAF of groundwater from existing wells over the fall period (September through November) results in a maximum drawdown of about 50 feet in the pumped aquifer compared to a maximum of approximately 40 feet of drawdown if the same production occurs in the summer.

Production of 150 TAF of groundwater from new deeper wells over the fall period results in a maximum of approximately 125 feet of drawdown in the pumped aquifer compared to a maximum of approximately 75 feet of drawdown if the same production occurs in the summer.

Production of 150 TAF of groundwater from existing wells over the summer/fall period (May through November) results in a maximum of about 30 feet of drawdown in the pumped aquifer compared to a maximum of approximately 40 feet of drawdown if the same production occurs in the summer only.

Production of 150 TAF of groundwater from new deeper wells over the summer/fall period results in a maximum of approximately 50 feet of drawdown in the pumped aquifer compared to a maximum of approximately 75 feet of drawdown if the same production occurs in the summer only.

For a given project production capacity, the greatest drawdown is observed in fall pumping simulations because the pumping occurs over 3 months, resulting in the highest instantaneous rate. An intermediate magnitude of drawdown is observed for the 4-month summer period, and the least drawdown is predicted for the 7-month summer/fall pumping cycle.

The production of groundwater from the deeper aquifer from new production wells results in the greatest predicted magnitude of drawdown. This is because the pumping is simulated to occur in a 200-foot thickness of model Layer 6 (approximately 900 to 1,100 feet bgs) whereas the pumping from existing wells is assumed to occur from wells screened throughout the approximately 400-foot thickness of the regional aquifer (200 to 600 feet bgs). Further, the new well field identified on the western side of the valley is located further west, relative to the location of the existing wells, transferring the groundwater pumping stresses closer to the low permeability bedrock which borders the western edge of the alluvial aquifer.

Simulated drawdown in the vicinity of the eastern well fields in the Butte Basin Project are significantly lower than those observed on the west. This is due to a combination of lower overall production rates from the east and a greater production well spacing.

2.2.2 Effects on Surface Water Flows

Peak effects on stream flow due to groundwater production in the Sacramento Valley are summarized in Table 2-2.

TABLE 2-2
Peak Effects on Streamflow from Conjunctive Management Operations
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Scenario 1		**Scenario 2**		**Scenario 3**		**Scenario 4**	
Stream	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**
All Streams	54	53	111	105	80	90	64	65
Butte Creek	13	12	72	69	50	48	39	33

TABLE 2-2
Peak Effects on Streamflow from Conjunctive Management Operations
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Scenario 1		**Scenario 2**		**Scenario 3**		**Scenario 4**	
Stream	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**
Sacramento River – GCID to Wilkins Slough	42	37	32	28	16	18	16	15
Feather River	3	3	6	6	4	4	4	4
Little Chico Creek	3	3	6	5	4	3	4	3
Salt River	1	5	5	8	2	5	2	5
Stone Coral Creek	6	9	11	15	7	10	6	9
Stony Creek	4	5	7	7	4	6	4	4

Specific conclusions regarding surface water effects are as follows:

- The higher pumping rates associated with the 300-TAF projects clearly result in significantly larger peak stream impacts.
- For a conjunctive management project of a given size, new well fields pumping from deeper aquifers tend to produce greater peak stream impacts on western streams than pumping from existing wells tapping the regional aquifer. This is likely due to the greater magnitude of drawdown predicted on the western side of the valley from new wells as discussed above. Effects on eastern and central streams (Sacramento River) are similar.
- When looking at the cumulative peak impacts to all streams, the lower project pumping rates (150 TAF over 4 or 7 months) predict similar peak impacts for both new and existing well fields. At moderate production rates (150 TAF over 3 months), peak impacts of new wells is greater than those produced by existing wells. At the highest production capacity (300 TAF over 4 months), the existing well field produces greater peak impact to streams than the new well field.
- For all projects evaluated, peak stream impacts occur in 1990, as do peak impacts on the Sacramento River. This is also generally true of the west side streams of Stone Corral and Stony Creek.
- For all projects evaluated, peak stream impacts on the east side streams (Little Chico Creek and Butte Creek) occur in early 1995. One exception is that for the 300 TAF projects, peak impact on Butte Creek occurs in early 1993.
- Peak impacts on the Feather River occur in late 1994 or early 1995.

SECTION 3
Technical Analysis and Modeling

Technical analysis and modeling of conjunctive management operations require consideration of both surface water and groundwater systems and their interaction. This project developed and used models that simulate each system using similar water demands and system operations. Information is passed between the models to depict conjunctive management operations and effects between the surface and groundwater systems. These tools were developed to simulate and compare a baseline condition and a project condition to determine benefits and effects of conjunctive management.

Technical analyses were performed at a planning level to help prove concepts and define potential conjunctive management configurations and operations. Analyses were conducted for general projects, locations, and operations. More specific and refined analysis will be required as specific projects are defined. Most of the analyses contained herein were conducted in a comparative, rather than absolute, manner, and results must be interpreted as such. Comparisons of benefits and impacts between different scenarios or well fields help inform decisions on what projects work better than others. Interpretation of the results should not be interpreted in a highly predictive manner, such as pumping “X” amount of groundwater results in a deficit of “Y” stream flow, or release of “A” volume of water from a reservoir accomplishes “B” amount of environmental restoration.

3.1 Objectives of Groundwater Analysis

Conjunctive water management, or groundwater substitution projects, can result in depressing local groundwater levels, which could affect yields and performance of nearby water supply wells and cause a reduction of groundwater discharge to surface streams or direct leakage from streams to underlying aquifers. Timing these impacts is critical, especially for surface water. Acceptable impacts to surface water flows during certain times of year might be unacceptable during other parts of the year. As part of the technical analysis, a numerical groundwater modeling tool was developed to evaluate impacts of proposed conjunctive water management projects on groundwater levels and streamflows near proposed project sites. The groundwater model is regional in scale, covering the Sacramento Valley Groundwater Basin. This model uses transient surface water budgets developed from spatially referenced land use data, water district operations, surface water availability, and required supplementary groundwater pumping to meet agricultural demands. Specific objectives of the groundwater modeling effort included the following:

- Calculating transient valley-wide and project-specific drawdown in groundwater levels resulting from implementing conjunctive management projects at two general locations with the northern Sacramento Valley.
- Quantifying transient impacts to streams resulting from implementing conjunctive management projects.

- Considering the effects of operating conjunctive water management projects in both wet and dry hydrologic periods and operating projects only in certain selected years within a longer hydrologic period.

3.2 Objectives of Surface Water Analysis

A surface water model was developed to simulate coordinated operation of select Central Valley Project (CVP) and State Water Project (SWP) reservoirs with conjunctive management projects. The surface water model was designed for use in gaming sessions and to help improve understanding of tradeoffs associated with different project objectives and operations. Specific objectives of the surface water modeling included the following:

1. Quantifying additional water supply that might be developed with conjunctive management projects and how that water supply can be used to meet agricultural and environmental objectives.
2. Understanding how conjunctive management projects might change the operation of CVP and SWP reservoirs, including effects on storage, spills, and risks to existing contracts and cold water pool management.
3. Understanding tradeoffs and risks associated with different conjunctive management operations, project sizes, and project objectives.
4. Improving understanding of how changes in stream-aquifer interactions might result in changes to the surface water system.
5. Understanding the effects on other parts of the system, including other reservoirs, hydropower operations, the Sacramento-San Joaquin River Delta (Delta), and south-of-Delta water supplies.

SECTION 4

Current Basin Groundwater Conditions

The initial intent of the Project was to identify areas within the Sacramento Valley groundwater basin in which groundwater levels were significantly lowered due to agricultural pumping for extended periods of time and persisted through the winter recharge period. Conditions of this type would indicate the presence of a large unsaturated aquifer volume that could be used to implement a put-then-take groundwater banking program. Under a program of this type, surface water is delivered to existing groundwater users in the target area during years of above average precipitation, resulting in a replenishing aquifer storage characterized by increased groundwater levels. When dry conditions return to the area, groundwater held in storage within the aquifer is pumped to yield additional supply to meet project objectives.

The first step in the evaluation process was to identify areas within the Sacramento Valley groundwater basin that would be suitable for a put-then-take type conjunctive management project. This was done by collecting and evaluating numerous historical groundwater level hydrographs from wells throughout the basin. Results of this analysis indicated that while numerous areas within the basin show drawdown during the irrigation season, groundwater levels in most areas essentially recover during subsequent winter months, with the exception of the occurrence of multiple years of critically dry conditions. Figures 4-1 through 4-15, which depict historic groundwater fluctuations in wells distributed throughout the valley. The conclusion from this analysis was that a put-then-take water bank was not feasible in the Sacramento Valley north of the American River Basin. Providing surface water for irrigation demands in lieu of groundwater does not result in increased groundwater in storage because groundwater levels recover due to natural recharge over the winter months.

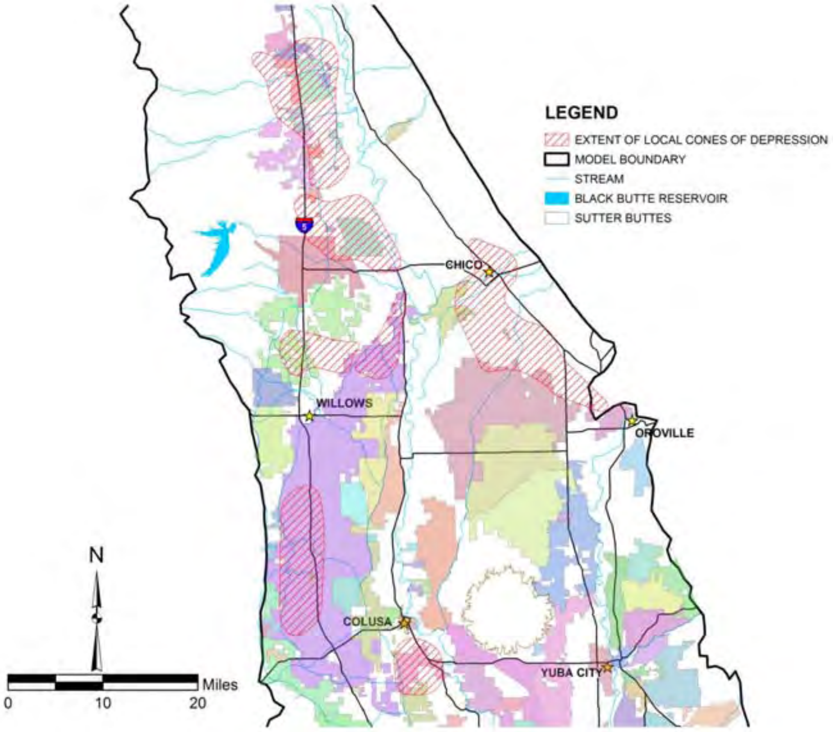


FIGURE 4-1
GROUNDWATER CONDITION STUDY AREAS
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

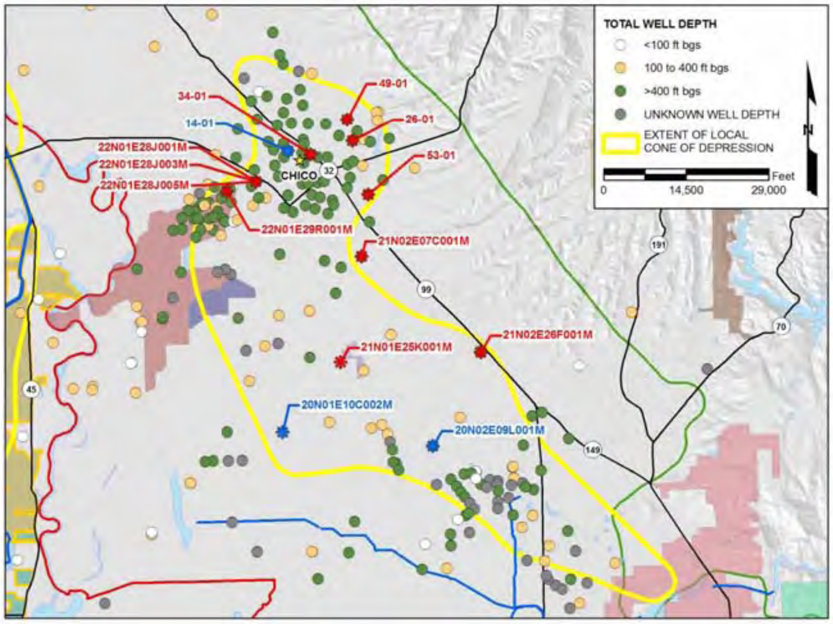


FIGURE 4-2
WELLS EVALUATED IN THE CHICO-DURHAM AREA
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

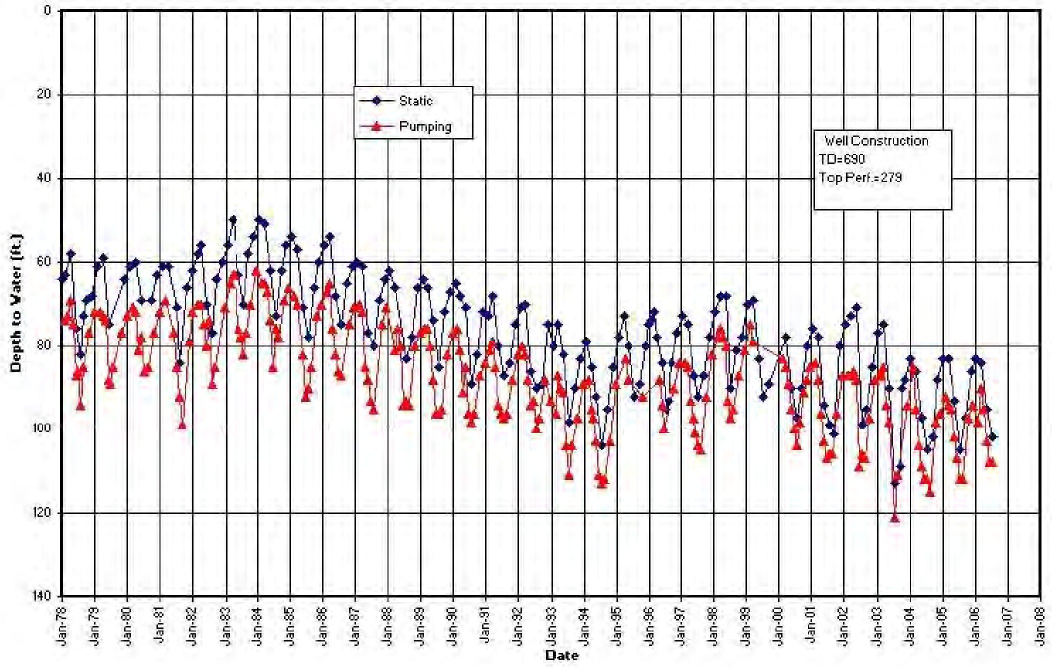


FIGURE 4-3
HYDROGRAPH OF CAL WATER WELL 34-01
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

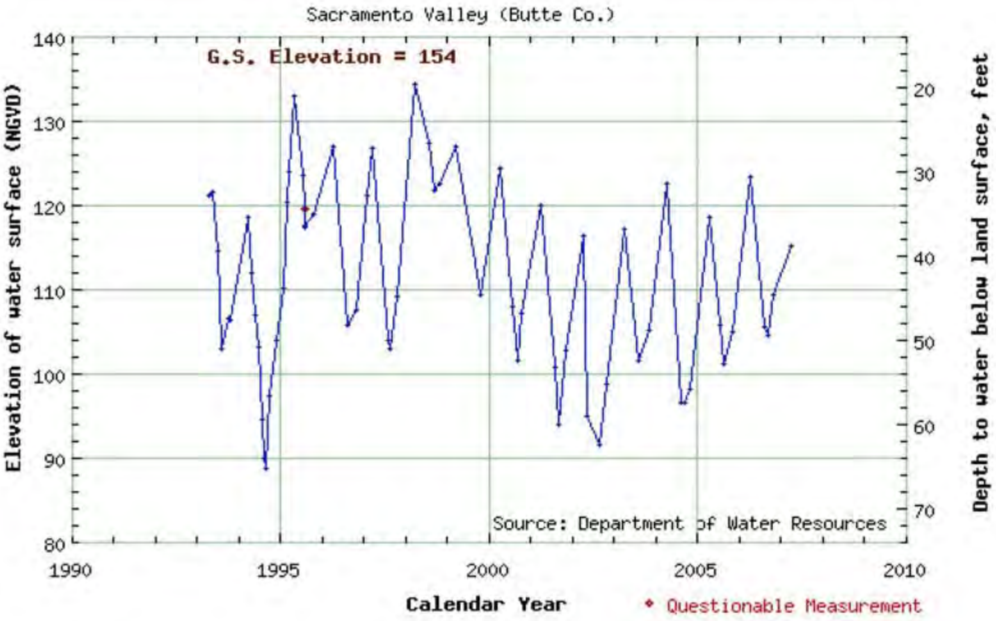


FIGURE 4-4
HYDROGRAPH OF WELL 21N01E25001M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

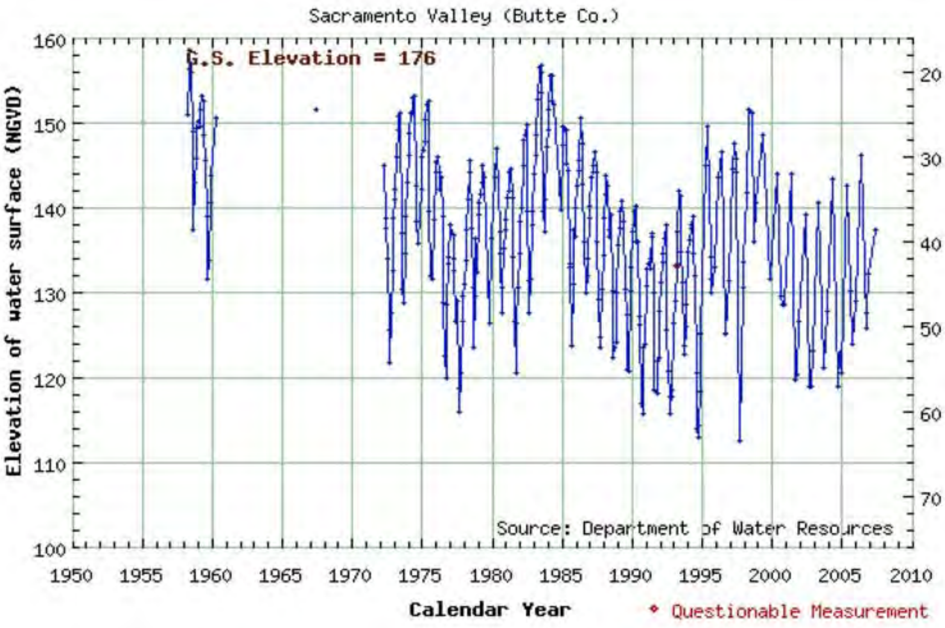


FIGURE 4-5
HYDROGRAPH OF WELL 22N01E28J001M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

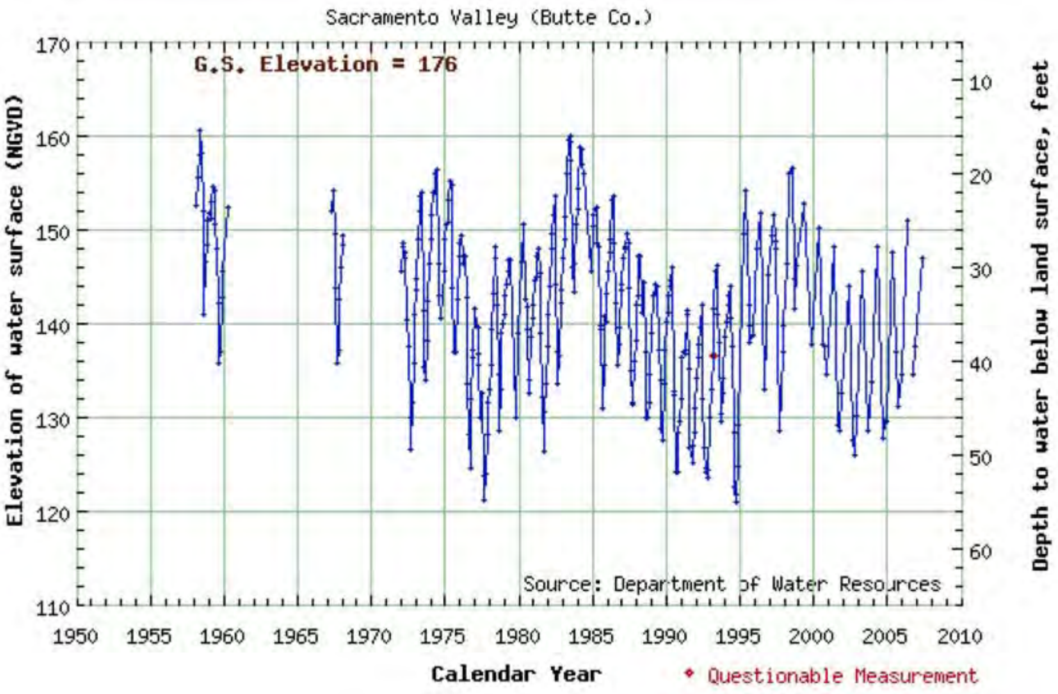
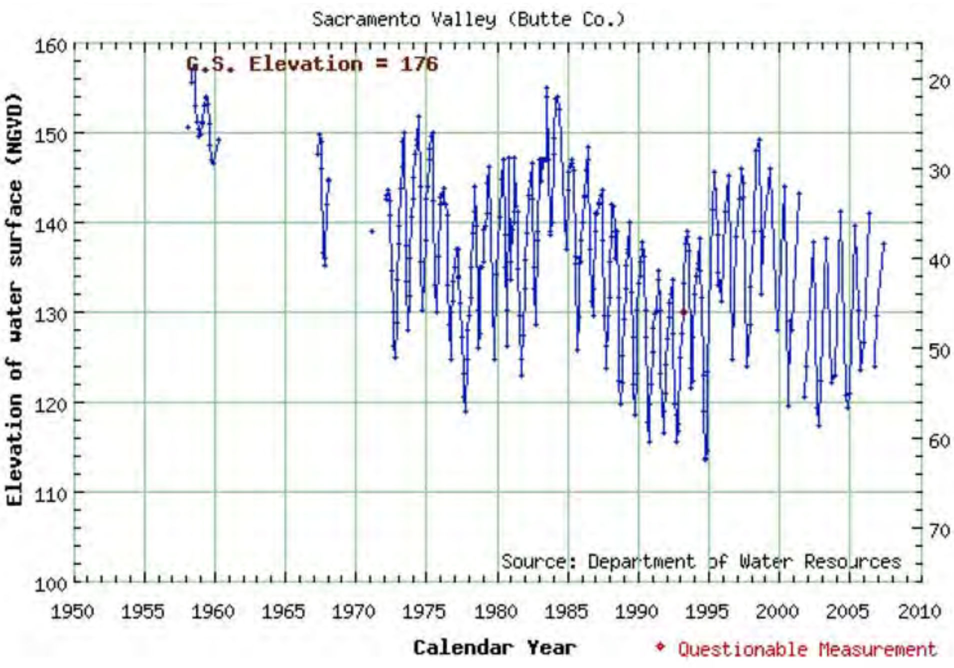


FIGURE 4-6
HYDROGRAPH OF WELL 22N01E28J003M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT



Source: Department of Water Resources

FIGURE 4-7
HYDROGRAPH OF WELL 22N01E28J005M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

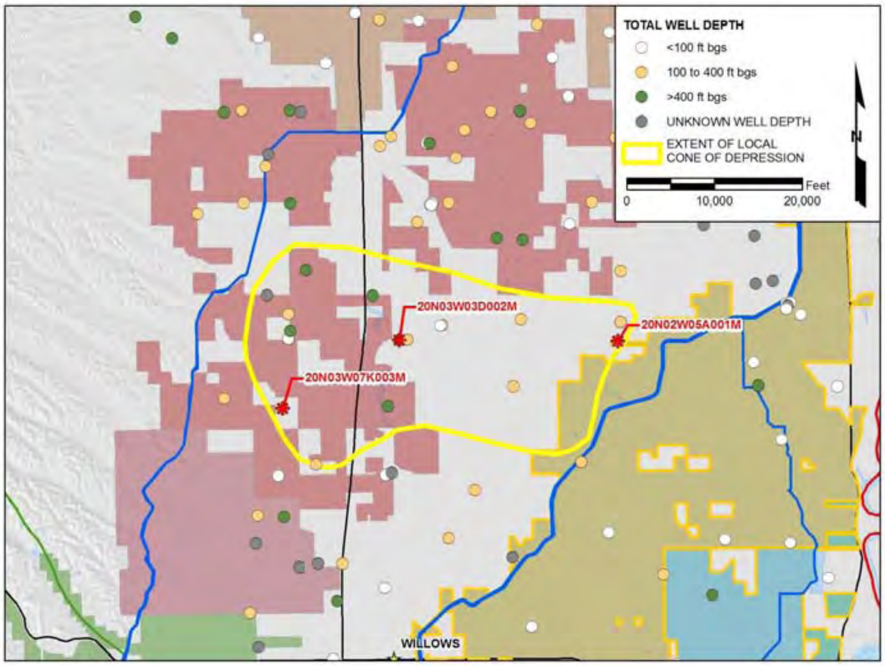


FIGURE 4-8
WELLS EVALUATED IN THE ORLAND-ARTOIS WATER DISTRICT AREA
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

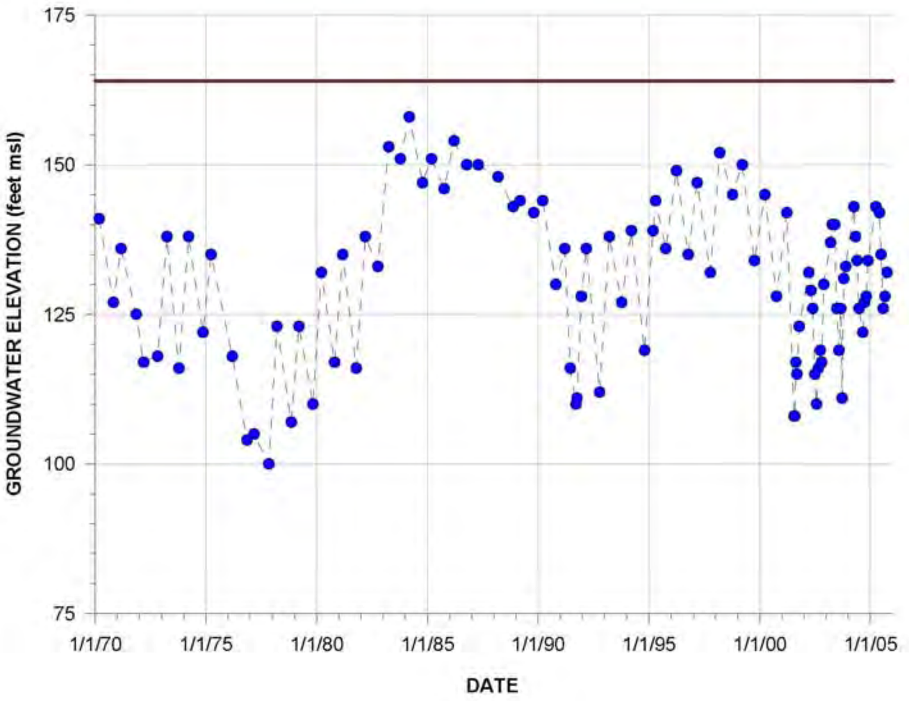


FIGURE 4-9
HYDROGRAPH OF WELL 20N03W03D002M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

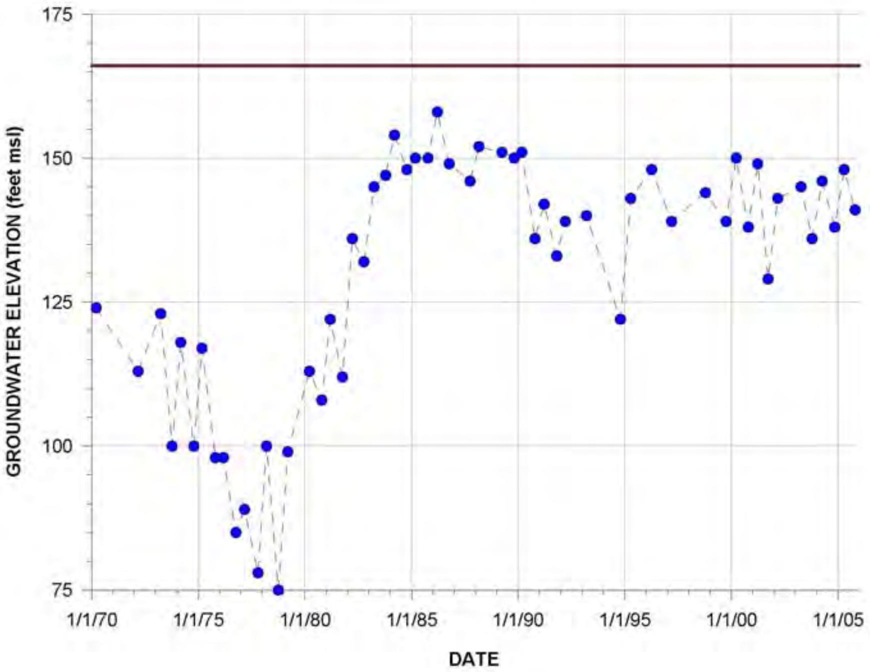


FIGURE 4-10
HYDROGRAPH OF WELL 20N03W07K003M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

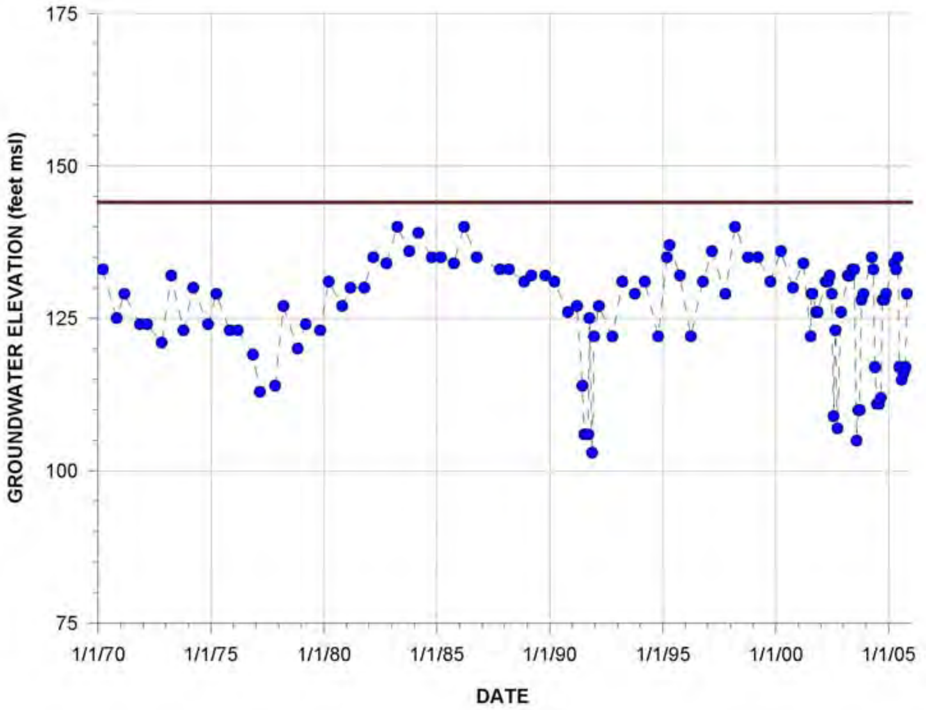


FIGURE 4-11
HYDROGRAPH OF WELL 20N02W05A001M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

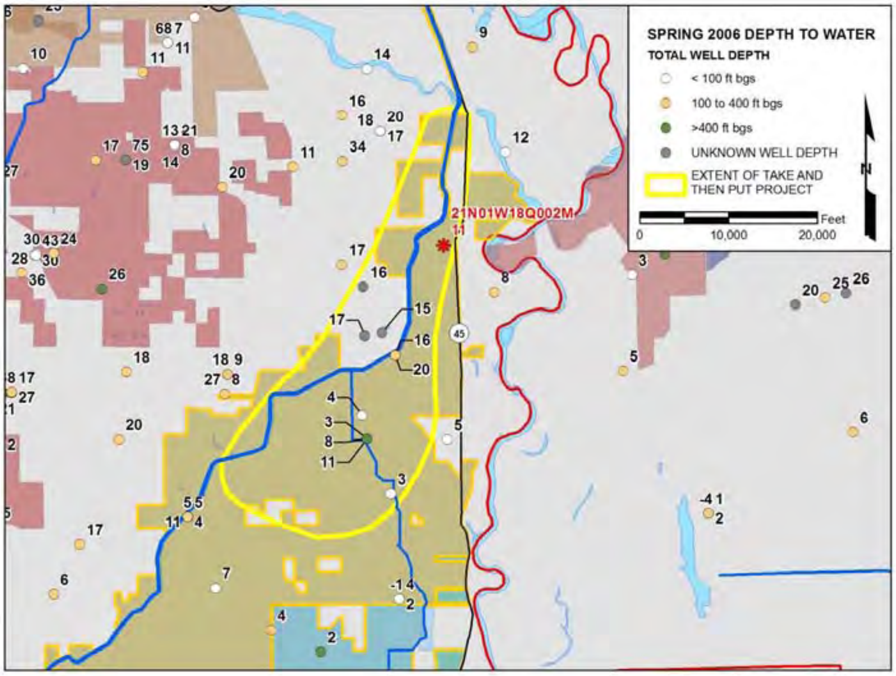


FIGURE 4-12
WELLS EVALUATED IN THE NORTHERN GCID WATER DISTRICT AREA
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

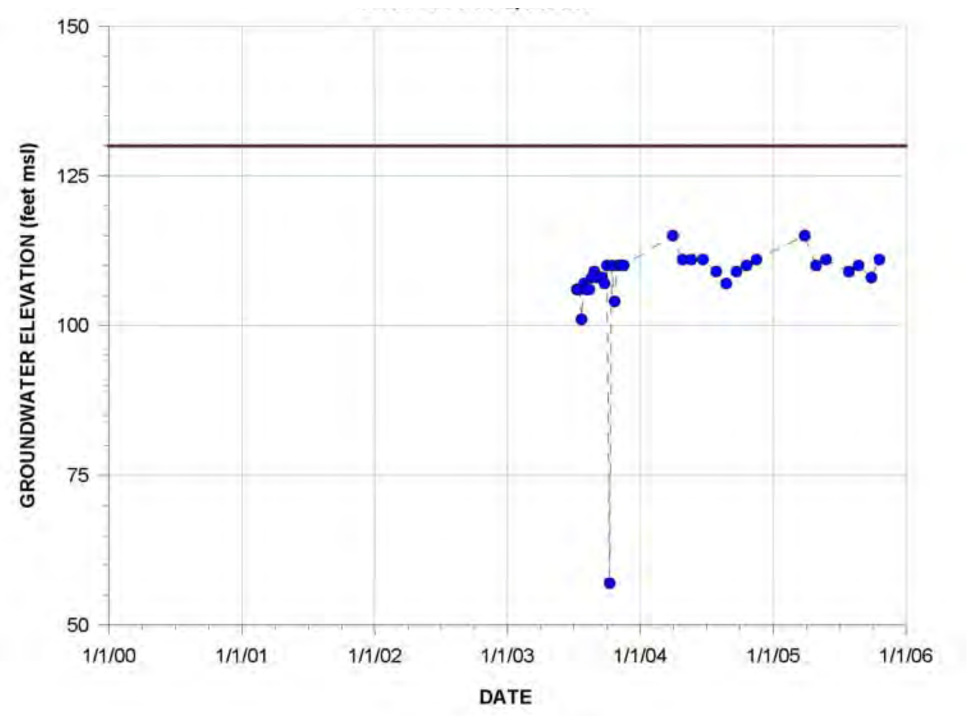


FIGURE 4-13
HYDROGRAPH OF WELL 21N01W18Q002M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

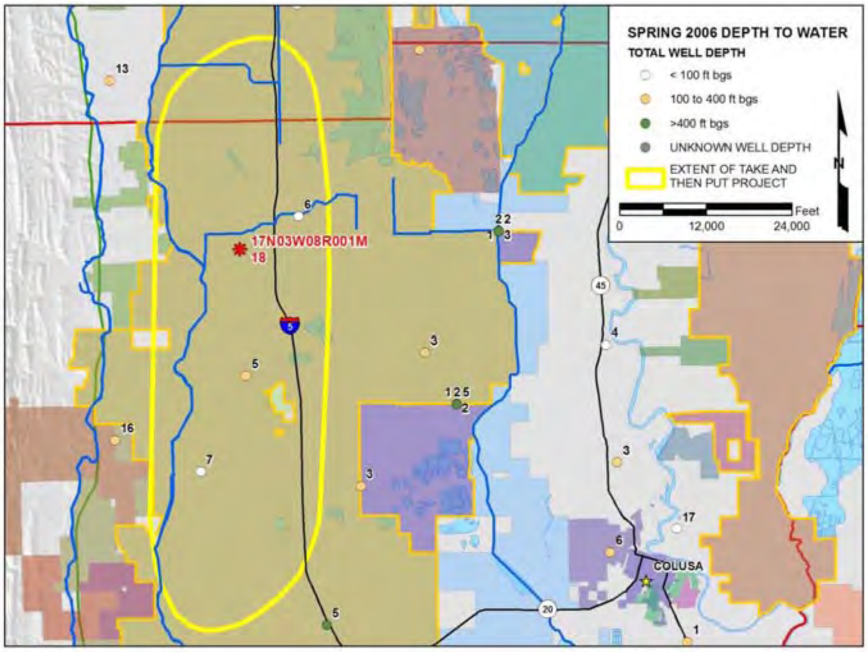


FIGURE 4-14
WELLS EVALUATED IN THE CENTRAL GCID WATER DISTRICT AREA
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

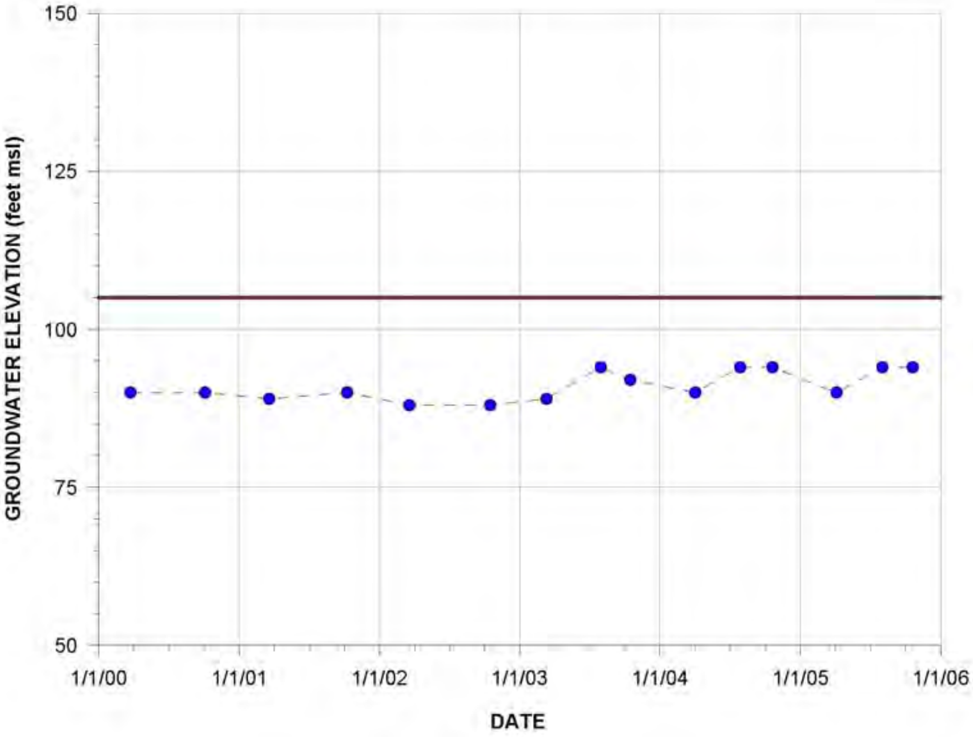


FIGURE 4-15
HYDROGRAPH OF WELL 17N03W08R001M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

SECTION 5

General Operational Scenario

The team used its understanding of annual aquifer drawdown and recovery to develop a conjunctive operation configuration that relies primarily on re-operation of existing reservoirs to achieve the project objectives, drawing on groundwater as a backstop. The term "backstop" refers to the potential to use groundwater supplies on a temporary basis to make up for shortfalls in surface water supplies due to modified project operations. Groundwater provides an additional source of water to protect surface water reservoirs from being excessively depleted. This type of operation offers different opportunities and challenges than the conventional put-then-take groundwater banking discussed above. Surface water is not banked in the aquifer in wet years and recovered during dry years. Instead, additional water is released from surface reservoirs for delivery to meet Project objectives (unmet local irrigation demands and environmental flow targets). These releases result in lower end-of-year reservoir storage levels and more reservoir space available to capture winter runoff.

The goal of this operation is to develop additional water supply by refilling reservoir space vacated by additional Project releases with surplus surface water that otherwise is released for flood control. In years when refill is not complete, Project pumping produces groundwater for use in Project areas in lieu of surface water deliveries that would otherwise be made from reservoirs. This allows an equivalent volume of water to remain in reservoir storage to recover from prior year project releases.

This mode of conjunctive operation, in which reservoir operation is used as the primary means to develop new water supply and groundwater is used infrequently as a backstop, is highly efficient because it reduces the frequency and volume of pumping as compared to traditional banking operations. Groundwater pumping is relied upon only as needed to maintain reservoir storage when refill from surplus winter flows is insufficient.

In some years, conditions in the Sacramento Valley may be so critically dry that Project pumping would be suspended altogether. For instance, if groundwater levels were already at levels of concern (according to county Basin Management Objectives or other standards), Project wells would be turned off and the Project would generate no new supplies under these conditions.

SECTION 6
Initial Project Site Identification

The project team completed a systematic, qualitative assessment of conditions within the Sacramento Valley to identify particular areas in which conjunctive operations appear promising. This process did not conclusively identify the very best or most feasible sites, but did identify particularly promising sites for conjunctive operations.

The team examined fall groundwater elevation maps, water district maps, and water source maps. Initially it was assumed that conjunctive management operations would follow groundwater banking type operations wherein water is stored in aquifers during years of above normal precipitation and extracted during years of below normal precipitation. These operations are typical in the San Joaquin Valley and other areas in which aquifers have been depleted and appreciable storage space exists. Following this initial assumption, the following two types of sites were identified:

- Areas in which existing groundwater levels may be lower than surrounding areas and overlying lands are supplied almost exclusively from groundwater. This type of site may provide the potential for storage of surplus surface water in underlying aquifers.
- Areas in which minimal groundwater pumping exists because overlying areas are supplied almost exclusively from surface water. This type of site may provide a potential area for groundwater extraction.

6.1 Initial Project Sites

An initial list of project sites was developed from a review of groundwater maps and knowledge of the Sacramento Valley. Sites were identified by the overlying water district, though projects did not strictly conform to water district boundaries. Information considered in this analysis included the location, water source, existing surface water contracts, infrastructure available and additional infrastructure necessary for delivery of surface water and extraction of groundwater, conceptual operations, and information on existing groundwater conditions. Table 6-3 summarizes this information for the nine initial sites.

6.2 Selection Criteria

The main goal was to identify at least one site that is served by the CVP (Shasta), one by the SWP (Oroville), and one by the Orland Project. The CVP and SWP are the principal surface water systems in the Sacramento River basin and their operations are linked to the Sacramento and Feather Rivers, respectively, both of which are targeted for environmental restoration. The Orland Project, although not among the largest surface water systems in the Valley, is an area where conjunctive operations have been viewed as a possibility for many years.

TABLE 6-1
Initial Project Sites and Parameters
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Location	Water Source	Site Type	Annual Surface Water Contract	Project to Integrate With	Currently Integrated?
Butte Basin	Surface	Extraction	~ 300 TAF/yr	SWP	Yes
Orland-Artois WD	Mixed	Both	53 TAF/yr	CVP	Yes
Rancho Capay WD	Ground	Storage	None	CVP	No
Corning Canal Area	Mixed	Both	33 TAF/yr	CVP	Yes
Yolo-Zamora WD	Ground	Storage	None	CVP	No
Glenn-Colusa ID	Surface	Extraction	825 TAF/yr	CVP	Yes
Stony Creek Fan area	Surface	Extraction	~ 100 TAF/yr	Orland	No
Colusa County WD	Mixed	Both	68 TAF/yr	CVP	Yes
Olive Percy Davis Ranch	Surface	Extraction	32 TAF/yr	CVP	Yes

These nine sites were evaluated based on whether they could meet project objectives of providing additional water supply to meet agricultural and environmental objectives, an estimate of the volume of water that may be developed, and relative (compared to the other sites) ease and cost of integrating the project with existing surface water systems.

The following additional criteria were used to identify prospective sites:

- Availability of reliable surface water supplies that could be substituted with groundwater to enable conjunctive operations
- The presence of highly productive, underlying groundwater aquifers that could be economically developed
- The ability to locate and design production wells in a manner that would minimize effects on existing groundwater users and surface streams

6.3 Selected Project Sites and Operational Scenarios

Using the selection criteria described in Section 5.2, the Project identified two sites on which to conduct more refined analyses with surface and groundwater modeling tools. The GCID and Butte Basin Projects, supplied by the CVP and SWP, respectively, provided the potential to develop the largest quantity of water compared to other sites, and are already well integrated with the surface water system.

Additionally, the Stony Creek Fan and Orland Project was identified as a third potential project. However, upon further investigation into potential groundwater pumping capacities and the ability to integrate the project with the Sacramento River system, it was determined that this project would not be modeled during this phase of the project. This project is retained for additional analysis in future phases of investigation.

6.3.1 Glenn-Colusa Irrigation District Project

GCID is the largest, single Sacramento River diverter, serving about 141,000 acres of irrigated land and 20,000 acres of managed waterfowl habitat within its gross service area of 170,000 acres. GCID is served by the CVP (pursuant to underlying senior water rights) and is underlain by productive aquifers. There are about 200 existing private wells in GCID, but groundwater production in most years is small. Conjunctive management operations would utilize wells within GCID as a backstop for a more aggressive operation of Shasta Reservoir.

6.3.2 Butte Basin Project

The initial project site of Western Canal Water District was expanded to include neighboring Richvale Water District. These districts are all served by the SWP (pursuant to underlying senior water rights) and are adjacent to each other comprising a total irrigated area of roughly 110,000 acres. They are generally underlain by productive groundwater systems and there is limited existing use of groundwater. Conjunctive management operations would utilize wells within the two districts as a backstop for a more aggressive operation of Oroville Reservoir.

SECTION 7

Modeling Overview

Evaluating conjunctive management projects requires simulation of both surface water and groundwater systems. Simulating the surface water system is necessary to determine when water is available to refill reservoirs and estimate unmet agricultural demands, environmental objectives, and flow conditions. A groundwater model is necessary to estimate the effects of additional pumping on aquifer systems, including the spatial extent and magnitude of drawdown and potential change in stream-aquifer interaction. Changes in stream-aquifer interactions may affect the surface water system, depending on stream conditions when the changes occur. For example, if additional pumping results in more stream loss to the aquifer or less aquifer contribution to stream flow during the winter season of relatively wet years when the surface water system has surplus flow, there may be little or no impact. However, if pumping reduces stream flow during months and years when the surface water system is being operated to meet specific flow or water quality requirements, any reduction in stream flow will require a corresponding increase in reservoir release to ensure the flow requirement continues to be met. This decreases the water supply benefit of conjunctive management projects. Evaluating this aspect of conjunctive management projects requires interaction between surface water and groundwater models.

The main tool used to evaluate alternative conjunctive management operations strategies and test alternative environmental flow thresholds and priorities is a spreadsheet-based surface water model. It is set up to simulate changes in operation of Lake Shasta and Lake Oroville relative to conditions depicted in a baseline CalSim II simulation of CVP and SWP operations. The CalSim II baseline provides time series of reservoir storage levels, stream flows, and water deliveries which are used by the surface water model. Conjunctive management operations are simulated and layered onto baseline operations based on user inputs, while maintaining compliance with existing CVP and SWP rules, regulation, and operations.

The surface water model treats the groundwater system as a source of water and does not simulate groundwater flows or conditions. It does, however, include features to account for estimated effects of groundwater pumping on stream flow accretion and depletion through use of functions derived from complementary simulations of pumping in the groundwater model. These functions provided a coarse but adequate representation of stream-aquifer interaction so that the surface water model could be used for gaming sessions without having to operate the groundwater model. Final scenarios were evaluated using actual changes in stream-aquifer interaction based on complimentary groundwater model simulations.

Figure 7-1 illustrates inputs to the surface water model and resulting simulation of conjunctive management projects integrated into CVP and SWP operations.

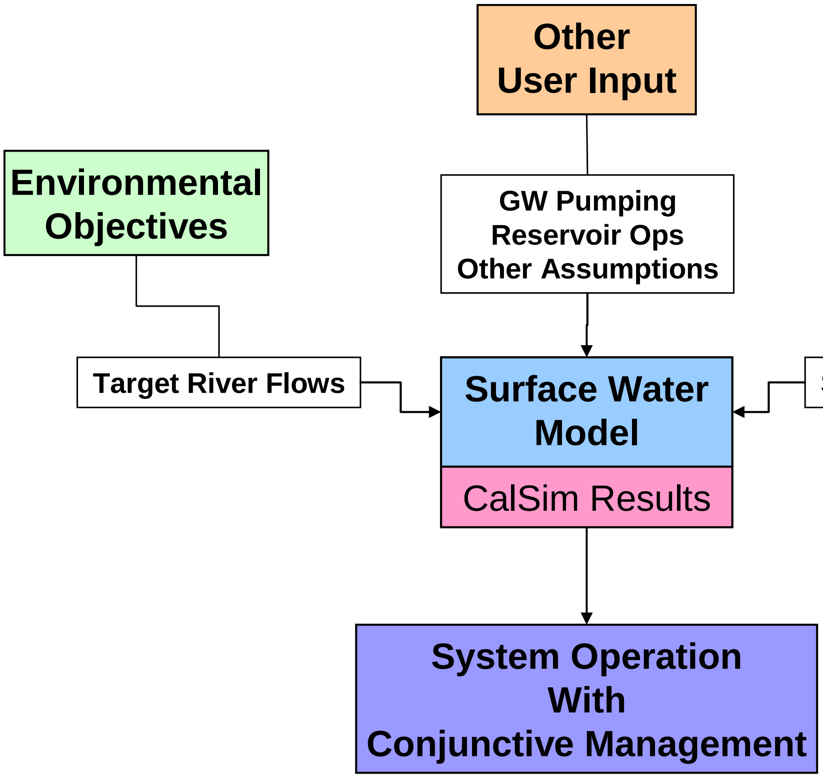


FIGURE 7-1
SURFACE WATER MODEL INPUTS AND OPERATIONS
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Numerous improvements were made to previously existing modeling tools, and new tools were developed for this analysis of conjunctive management projects. For the groundwater analysis, an existing simplified groundwater modeling tool was completely re-designed and improved, to yield an extremely powerful analytical package now referred to as the Sacramento Valley Groundwater Model (SACFEM). The basis for the SACFEM model was a simplified superposition-based groundwater model previously developed to support the Sacramento Valley Water Management Program. That model represented a very simplified depiction of the Sacramento Valley aquifer system as no recharge components to the aquifer system (deep percolation of precipitation and applied water) or discharge components (regional agricultural pumping) were included, and therefore the model could only compute the incremental change in groundwater levels and streams flows during the irrigation season. It was assumed that the aquifer system fully re-filled every winter, and each year of pumping was independent of previous aquifer stresses.

The SACFEM model is a full water budget based transient groundwater flow model that incorporates all of the groundwater and surface water budget components on a monthly time step over the period of simulation. This model provides very high resolution estimates of groundwater level and streamflow effects due to conjunctive water management pumping across the valley.

The surface water model is a new tool designed specifically to analyze conjunctive management projects for agricultural and environmental benefits. Its flexibility for use in gaming sessions and for sensitivity and tradeoff analysis helped provide understanding of conjunctive management concepts, operations, and limitations.

The integration of surface water and groundwater modeling tools and the simulation of effects of additional groundwater pumping on the surface water system is a significant advancement over previous modeling tools. Simulation of changes in stream-aquifer interaction, the spatial and temporal variations in those changes, and conditions in the surface water system when changes occur are key components for evaluating conjunctive management projects and understanding their benefits and risks.

SECTION 8

Groundwater Model

MicroFEM© (Hemker, 1997), an integrated groundwater modeling package developed in The Netherlands, was chosen to simulate the groundwater flow systems in the Sacramento Valley Groundwater Basin. The current version of the program (3.60) has the ability to simulate up to 25 layers and 250,000 surface nodes. MicroFEM© is capable of modeling saturated, single-density groundwater flow in layered systems. Horizontal flow is assumed in each layer, as is vertical flow between adjacent layers.

MicroFEM© was the chosen modeling platform for both basins for the following reasons:

- The finite-element scheme allowed the construction of a model grids covering large geographic areas (over 5,955 square miles in the Sacramento Valley Groundwater Basin) with coarse node spacings outside of the simulated project areas and finer node spacings in areas of interest (e.g., near potential project areas). The finer node spacing near simulated production wells provides greater resolution of simulated groundwater levels and stream impacts.
- The graphical interface allows rapid assignment of aquifer parameters and allows proofing of these values by graphical means.
- The flexible post-processing tools allow for rapid evaluation of transient water budgets for model simulations and identification of changes to stream discharges and other water fluxes across the model domain.

8.1 Geologic Setting

The Sacramento Valley Groundwater Basin is a north-northwestern trending asymmetrical trough filled with as much as 10 miles of both marine and continental rocks and sediment (Page, 1986). On the eastern side, the basin overlies basement bedrock that rises relatively gently to form the Sierra Nevada, and on the western side, the underlying basement bedrock rises more steeply to form the Coast Ranges. Marine sandstone, shale, and conglomerate rocks that generally contain brackish or saline water overlie the basement bedrock. The more recent continental deposits, overlying the marine sediments, contain fresh water. These continental deposits are generally 2,000 to 3,000 feet thick (Page, 1986). The depth (below ground surface [bgs]) to the base of fresh water typically ranges from 1,000 to 3,000 feet (Bertoldi et al., 1991).

In the Sacramento Valley Groundwater Basin, groundwater users pump primarily from deeper continental deposits. Groundwater is recharged by deep percolation of applied surface water and rainfall, infiltration from streambeds, and lateral inflow along the basin boundaries. The quantity and timing of snowpack melt and precipitation events are the predominant factors affecting the surface water and groundwater hydrology, and peak runoff in the basin typically lags peak precipitation by 1 to 2 months (Bertoldi et al., 1991).

8.2 Hydrology

The Sacramento River is the main surface water feature in the Sacramento Valley Groundwater Basin. It has several major tributaries draining the Sierra Nevada, including the Feather, Yuba, and American Rivers. Stony, Cache, and Putah Creeks drain the Coast Range and are the main westside tributaries of the Sacramento River.

8.3 Model Construction

8.3.1 Spatial Grid

The SACFEM model grid consists of 88,922 nodes and 177,095 elements. Nodal spacing varies from as large as 5,800 feet (1,750 meters) near the model boundary and in areas with no water management projects to as small as 500 feet (150 meters) in areas where groundwater production is being investigated. Three zones of refined nodal spacing are located throughout the model domain in proximity to the areas that were previously identified as showing the greatest potential for successful conjunctive water management operations (NHI, 2007). These three areas are located in the west-central portion of GCID, the areas southwest of Chico encompassing the Western Canal and Richvale Water Districts, and the area east of Black Butte Lake on the Stony Creek Fan (see Figure 8-1).

The finer spacing in these areas of interest allows for a more refined estimate of the groundwater levels and groundwater-surface-water interaction in the potential project areas. The model boundary represents the extent of the freshwater aquifer in the Sacramento Valley.

8.3.2 Vertical Layering

The total model thickness represents the thickness of the freshwater aquifer (less than 3,000 micromhos per centimeter) as defined by Berkstresser (1973) and subsequently refined in the northern portion of the valley by the California Department of Water Resources (DWR) (2002). For the southern portion of the model area, defined by Berkstresser data, elevation contour lines of the base of fresh water, along with information from boring locations (point measurements of the elevation of the base of fresh water) were digitized and used to generate an x, y, z file containing the elevation of the base of fresh groundwater at regularly spaced intervals. For the northern portion of the model area, the locations of the geologic cross-sections were plotted, along with the estimated base of freshwater elevations obtained from the cross-section information, and a base of freshwater elevation contour map was constructed. These data sets were then merged to yield a single interpretation of the structural contour map of the base of freshwater across the Sacramento Valley. This map is presented on Figure 8-2.

Total Aquifer Thickness

To develop a total aquifer thickness distribution and, therefore, a total model thickness distribution, it was necessary to develop a groundwater elevation contour map and subtract the depth to the base of freshwater from the groundwater elevation contour map. The water level calibration targets for this groundwater modeling tool are the steady-state groundwater heads measured in calendar year 2000. Therefore, to develop a target groundwater elevation contour map, all available groundwater elevation measurements in the DWR Water Data Library were obtained from DWR central and northern district staff. These measurements were primarily collected biannually during spring and fall periods, and these values were averaged at each well location to compute an average water level at each well point. These values were then contoured, in conjunction with the streambed elevations for the 37 major streams included in the model, to develop a target groundwater elevation contour map for the year 2000. The distribution of the elevation of the base of freshwater was subtracted from this groundwater elevation contour map to yield an estimate of the distribution of the total aquifer thickness across the model domain.

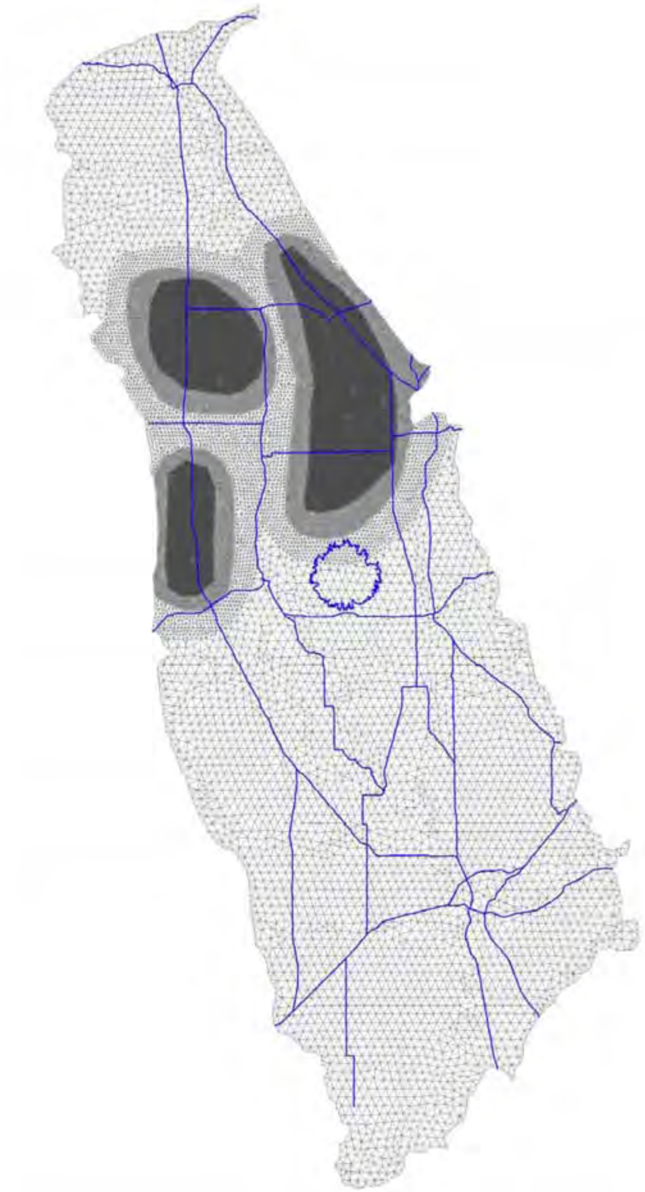


FIGURE 8-1
SACFEM FINITE ELEMENT GRID, LOWER TUSCAN CONJUNCTIVE WATER MANAGEMENT INVESTIGATION
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

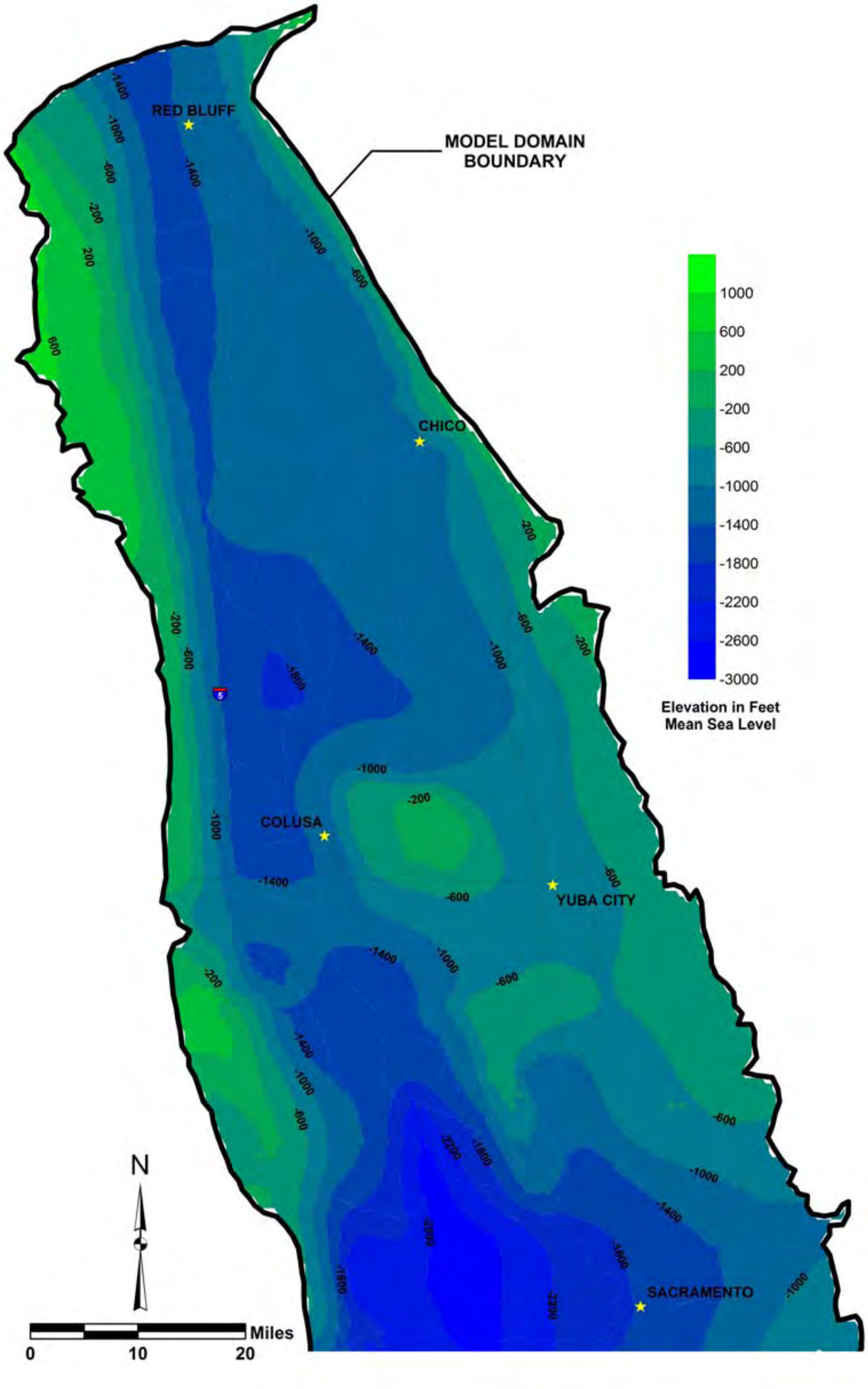


FIGURE 8-2
DEPTH TO FRESHWATER LOWER TUSCAN CONJUNCTIVE WATER MANAGEMENT INVESTIGATION
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Model Layer Thickness

Because one of the primary objectives of this analysis was to investigate the potential to implement conjunctive water management projects within the lower Tuscan aquifer, the strategy used to layer the model was to assign two layers to explicitly represent this aquifer system: layers 6 and 7. Where the lower Tuscan is present, the elevation of the top of layer 6 was defined by the structural contour surface of the top of the lower Tuscan. Two layers were assigned to represent this unit because in many areas of the model, the depth to the base of freshwater (the base of the model) is as much as 900 feet below the upper surface of the lower Tuscan. Groundwater production wells drilled into the lower Tuscan would almost certainly be screened over a much smaller depth interval. To represent this condition in the model, layer 6 was assigned a thickness of between 200 and 250 feet, with the remaining lower Tuscan thickness assigned to layer 7. The exception to this convention is in the northeastern portion of the model near the City of Chico. The lower Tuscan outcrops in the foothills above Chico; therefore, in these areas, all layers of the model represent the lower Tuscan aquifer. Moving west from Chico, a transition zone exists where a decreasing number of layers represent the lower Tuscan until it is limited to layers 6 and 7. In areas where the lower Tuscan is not present, the thicknesses of layers 6 and 7 represent 18 and 27 percent of the total aquifer thickness, respectively.

Layers 1 through 5 represent shallower producing zones within the valley. The thicknesses of these layers were assigned based on a specified percentage of the available aquifer thickness at a given location, to provide multiple depth zones within which to assign regional pumping. The assumed layer thicknesses for layers 1 through 5 were also selected to reflect typical screened intervals of production wells in the Sacramento Valley. Layer 1 represents approximately 6 percent of the total aquifer thickness, except along certain portions of model perimeter where the total aquifer thickness became very small. In these areas, layer 1 thickness was increased to up to 24 percent of the total aquifer thickness to improve numerical stability of flow calculations. The thicknesses of layers two through four each represent approximately 10 percent of the total aquifer thickness, and the thickness of layer 5 represents approximately 15 percent of the total aquifer thickness.

8.3.3 Boundary Conditions.

A combination of no-flow, specified flux, and head-dependent boundary conditions were used to simulate the groundwater flow system within the Sacramento Valley.

Head-Dependent Boundaries.

Rivers. A head-dependent boundary condition was chosen to simulate the streams within the Sacramento Valley. The MicroFEM© wadi system was used to implement streams within the model domain. MicroFEM©'s wadi package calculates the magnitude and direction of nodal fluxes based on the relative values of the user specified stream stage (wh1) and the calculated head in the upper aquifer (h1), but is limited by a critical depth (wl1). When calculated groundwater elevations fall below this critical depth, it is assumed that the water table de-couples from the river system, and the leakage rate from the river to the aquifer becomes constant. The equations that govern operation of the wadi package are as follows:

Groundwater discharge to a stream is simulated if h1 >wh1:

$$Q_{inflow} = a * (h1 - wh1) / | wc1 | \quad (1)$$

In coupled streams (groundwater elevation is above the stream bottom elevation), groundwater recharge from a stream is simulated if h1 <wh1:

$$Qinflow = a * (wh1 - h1) / | wc1 | \quad (2)$$

In de-coupled streams (groundwater elevation is below the stream bottom elevation), groundwater recharge from a stream is simulated:

$$Qinflow = a * (wh1 - wl1) / | wc1 | \quad (3)$$

Where:

Q = volumetric flux

a = nodal area

h1 = simulated groundwater elevation in layer 1

wh1 = simulated stream stage

wl1 = stream bottom elevation

wc1 = resistance across the streambed

Nodal area is a grid-dependent parameter that can be automatically calculated within MicroFEM©. In general, the nodal area around a node that represents a discrete reach in a stream is greater than the surface area of that stream along the reach in the field. The effective resistance term (wc1) incorporates an areal correction factor to account for this discrepancy. Additionally, streambed resistance terms account for the relationship between the streambed sediments and aquifer properties in the upper half of model layer 1 when calculating stream seepage. River resistances are calculated as follows:

$$wc1 = ((Dr/Kr) +((0.5 * mt1)/Kv1))* (a/LW) \quad (4)$$

Where:

Dr = thickness of streambed sediments

Kr = vertical hydraulic conductivity of streambed sediments

mt1 = thickness of model layer 1

Kv1 = vertical hydraulic conductivity of model layer 1

L = stream length represented by the model node

W = field-width of the wetted river channel within the stream reach represented by L

Most major streams in the Sacramento Valley were included in the groundwater flow model. A total of 37 streams are represented. Stream locations and elevations were digitized from existing base maps and USGS topographic quad sheets and imported into the model domain. Stream length within a given node is a grid-dependent variable calculated by MicroFEM© at each river node. The stream-length term is generally overestimated by MicroFEM© at stream confluences. Manual corrections of this term were made where necessary. Streambed thickness was assumed to be 3.28 ft (1 meter) for all river nodes.

Assumptions of streambed Kv were based on the type of streambed deposits expected based on stream size. Wetted stream width was calculated from aerial photographs at two locations along each stream.

Drains. Drain boundary conditions were specified across the top surface of the model excluding nodes where wadi boundaries exist. Drain boundary conditions are head-dependent boundaries that allow the transfer of water out of the model domain only. The elevation of the drain boundaries were set at the land surface. The drain boundaries were included in the model to represent a combination of surficial processes that occur in areas of shallow groundwater including evapotranspiration and groundwater discharge to the surface.

Groundwater discharge to a drain is simulated if h1 >dh1:

$$Q_{outflow} = a * (h1 - dh1) / | dc1 | \text{ (where a = nodal area)} \tag{5}$$

Groundwater discharge to a drain if h1 <dh1:

$$Q_{outflow} = 0 \tag{6}$$

The parameter dc1 represents the drain conductance and is a measure of the resistance to flow across the drain boundary. The dc1 parameter is computed as:

$$dc1 = ((Td/Kd) \tag{7}$$

Where:

Td is the drain interface thickness and Kd is the hydraulic conductivity of the drain materials.

Specified Flux Boundaries. There are three sets of specified flux boundary conditions used in the SACFEM model. They represent the following three primary components of the agricultural water budget:

- Deep percolation of applied water and precipitation along with agricultural pumping
- Mountain front recharge
- Urban pumping

Deep Percolation of Applied Water and Precipitation and Agricultural Pumping. The first set reflects the deep percolation of precipitation and applied water across the valley, as well as the regional agricultural pumping. The deep percolation flux values were applied to every surface node in the model. The pumping stresses due to agricultural and urban pumping were applied at selected locations in model layers 2 through 4. These layers were selected as they represent the common depths of production wells within the valley. The spatial distribution and magnitudes of these fluxes were derived from the surface water budget calculations described in greater detail in the subsection titled Surface Water Budget.

Mountain Front Recharge. The second set of specified flux boundary conditions represent the subsurface inflow of precipitation falling within the Sacramento River Watershed but outside the extent of the model domain. To estimate these flux values, the USGS 10-meter Digital Elevation Model (DEM) along with existing hydrography geographic information system (GIS) coverages for the Sacramento Valley were used to delineate the drainage areas that are tributary to the model domain but fall outside of the rivers watersheds explicitly represented in the model. It is these areas that can contribute water to the model domain but are not accounted for in the wadi boundary conditions defined in the model. Once the areas of these watersheds were defined, they were intersected with (PRISM) rainfall data using GIS PRISM tools, and the volume of precipitation falling on the watershed computed. Based on the computed total volume of precipitation, the deep percolation to the groundwater system was calculated using the empirical relationship developed by Turner (1991).

$$DP = (PPT-2.32)*(PPT)^{0.66} \tag{8}$$

Where:

DP = Average annual deep percolation of precipitation (in/yr)
PPT = Annual precipitation (in/yr)

Following is a summary of the process that was used to estimate the quantity of subsurface inflow, otherwise known as mountain front recharge:

1. The area of each drainage basin tributary to the model domain that is not represented by streams explicitly simulated in SACFEM was computed using a GIS-based analysis of the land surface topography. The extent of these smaller watersheds is shown on Figure 8-3.
2. Each drainage area polygon was then intersected with a GIS coverage of annual average rainfall estimated using the PRISM model (reference). This distribution of annual average rainfall was then used to calculate the total volume of rainfall falling on the watershed, and an overall average rainfall rate computed (inches per year).
3. The average rainfall rate was then used to compute a deep percolation quantity using the relationship between annual rainfall and deep percolation rate developed by Turner (1991).
4. The annual volume of deep percolation computed in step 3 was then converted into monthly values based on the monthly distribution of stream flow measured in unregulated sections of Deer Creek. These monthly deep percolation quantities were then introduced at the model domain boundary of each small watershed polygon using injection wells into layer 1. The quantity applied to each model boundary node was proportional to boundary length of each element versus to the total boundary length of the drainage polygon.

Urban Pumping. The final set of specified flux boundary conditions reflect urban pumping within the model domain. The distribution of agricultural pumping developed using the surface water budgeting methodologies described in the Surface Water Budget subsection do not include urban pumping. To estimate the quantity of urban pumping to apply to the model the year 2000 census data were used. Each municipal area with a population greater than 5,000, that uses groundwater as a source of municipal supply, was assigned a pumping volume based on an annual average per capita value of 250 gallons per capita per day. The urban pumping assigned to the Chico area as well as several northern Sacramento County municipal areas required a higher per capita rate to match the observed groundwater elevations in those areas. The monthly variability in urban pumping quantity was distributed based on typical seasonal trends for municipal water use.

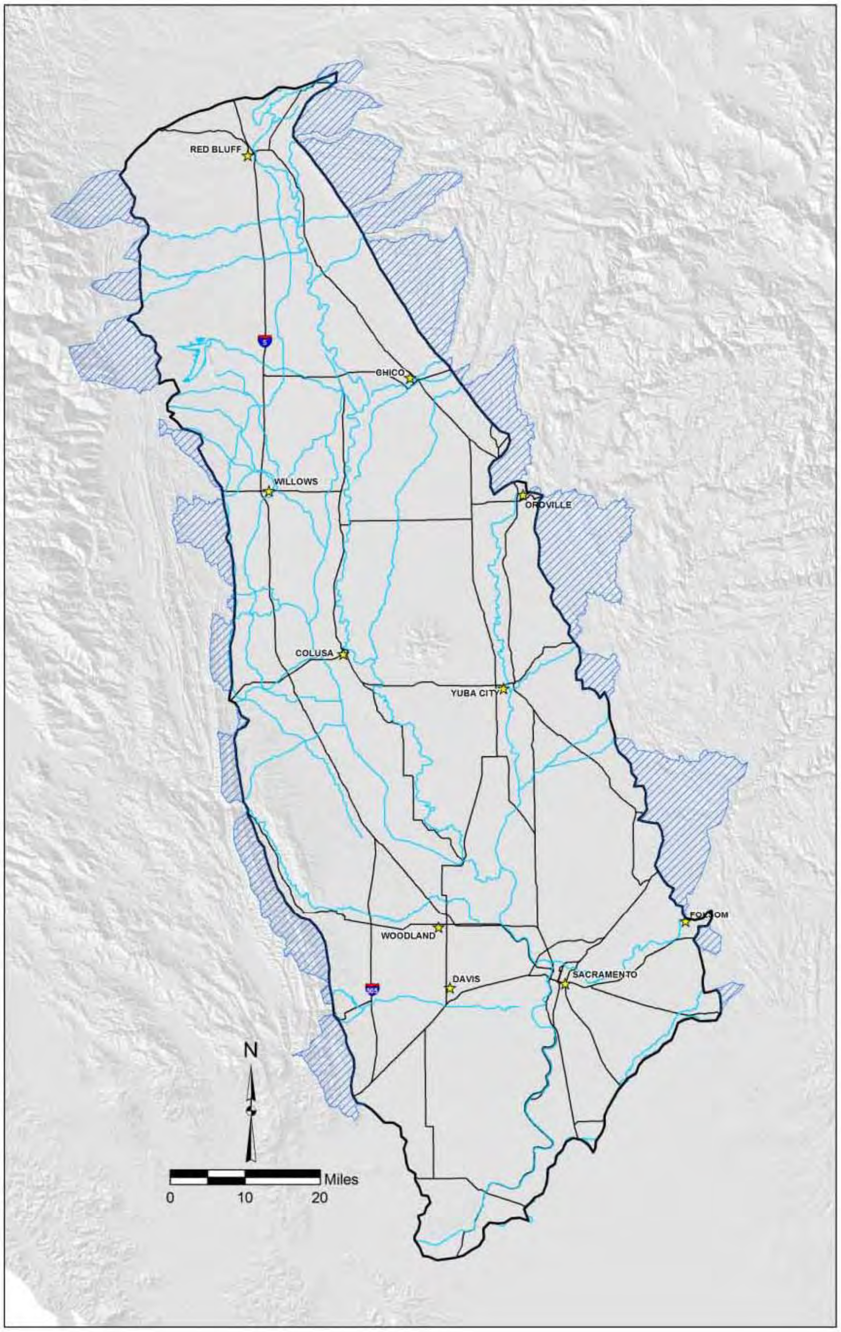


FIGURE 8-3
EXTENT OF POLYGONS USED TO ESTIMATE MOUNTAIN FRONT RECHARGE
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

No-Flow Boundaries. A no-flow boundary was specified across the bottom boundary of the model, representing the freshwater/brackish water interface.

8.3.4 Surface Water Budget

One of the most critical components to the successful operation of the SACFEM model is computation of transient surface water budget components. These water budget components were estimated based on a variety of spatial information including land use, cropping patterns, source of irrigation water, surface water availability in different year types and locations, and the spatial distribution of precipitation. Surface water budget components included in the model are deep percolation of applied water, deep percolation of precipitation, and agricultural pumping.

Surface water budgets were developed by intersecting existing GIS data developed by DWR with the groundwater model grid to develop land use for each groundwater model node. Additionally, GIS data on water districts and surrounding areas were used to identify district and non-district areas. The resulting intersection provided land use, water district, and water source information for each of the approximately 89,000 groundwater model nodes.

A semiphysically based soil moisture accounting model and historical precipitation data were used to simulate the root zone and calculate applied water demand and deep percolation past the root zone for each node. Calculated deep percolation was split between applied water and precipitation based on the season and the availability of water from each source.

Calculated values for deep percolation were compared to estimated values prepared by DWR’s Northern District for the year 2000. Northern District staff calculated detail water budgets in 2000 that included some of the best available estimates of regional deep percolation. In some areas soil parameters in the root zone model were adjusted to provide similar volumes of deep percolation. However, considerable uncertainty still exists in any estimate of regional deep percolation because soil conditions vary widely and it is not possible to measure deep percolation on a regional basis.

The total demand for applied water was used in conjunction with the water source and water district attributes from the GIS intersection to estimate agricultural groundwater pumping. Some areas are supplied solely from groundwater and calculated total applied water demand represents groundwater pumping. Other areas are supplied by a mix of groundwater and surface water. For these areas, estimates of the availability of surface water each year were made to determine the fraction of applied water demand met from surface and groundwater. In these areas, additional information on the overlying water district was combined with district water rights and contracts to estimate available surface water. For example, districts within the Tehama Colusa Canal Authority have water contracts with the Bureau of Reclamation (Reclamation) that receive different allocations each year. An estimate of those allocations from an existing level of development simulation of CVP operations was used to calculate the availability of surface water for groundwater model elements within those districts. Any remaining applied water demand, after consideration of available surface water, is assumed to be met from groundwater pumping.

Annual values of calculated agricultural pumping for the Sacramento Valley were reviewed and compared well to the generally accepted estimate of approximately 2.5 million acre-feet (DWR, 2005).

8.3.5 Aquifer Properties

The distribution of aquifer properties across the Sacramento Valley is poorly understood. In certain areas with significant levels of groundwater production, the collection of aquifer test data, and the measurement of historic groundwater level trends in response to known groundwater production rates have provided valuable information on aquifer properties. However in the majority of the valley, these data are not available.

To estimate the spatial distribution of aquifer properties across the model domain for this numerical modeling effort, a database of well productivity information was used. In consultation with DWR staff, a database was obtained that included all of the specific capacity yield data that were available from well log records. These data were compiled along with well construction information for each production well to yield a representative data set of well productivity across the valley. Wells that did not have available construction data were omitted from further consideration. To protect owner privacy, the exact location of each well was modified by DWR staff to reflect the center of the section in which each well was located. This modification in well location did not adversely affect the use of the data to estimate the spatial distribution of aquifer properties, given the extremely large area encompassed by the model domain. The total number of wells in the database within the model domain used in this analysis was approximately 1,000 wells.

The intent of the modeling analysis described herein is to simulate the operation of high-productivity irrigation wells screened within the major producing zones in the valley to support conjunctive water management projects. Therefore, the aquifer properties that are of primary interest are those of the major aquifer zones tapped by large-diameter irrigation wells. The well database described above was filtered to remove data obtained from tests on low yield and/or shallow domestic type wells. All test data from wells that reported a well yield below 100 gallons per minute (gpm) were eliminated from consideration as was the test data from wells with a total depth of less than 100 feet. The only exception to this second consideration was for wells that were located along the basin margins, where aquifers are thin, that reported what appeared to be valid test results. Data from these wells was considered as they were often the only data available in the basin margin areas.

Once the data set for consideration was finalized, the reported specific capacity data for each well was used to estimate an aquifer transmissivity for that location. The relationship used to estimate aquifer transmissivity was the following form of a simplified version of the Jacob non-equilibrium equation:

$$Sc = T/2000 \qquad (9)$$

Where:

Sc = specific capacity of an operating production well (gpm per foot of drawdown)
T = aquifer transmissivity (gallon per day [gpd] per foot)

After a transmissivity estimate was computed for each location, the transmissivity value was divided by the screen length of the production well to yield an estimate of the aquifer hydraulic conductivity. The final step in the process was to smooth the hydraulic conductivity field to provide regional scale information. Individual well tests produce aquifer productivity estimates that are local in nature, and may reflect small scale aquifer heterogeneity that is not necessarily representative of the basin as a whole. To average these smaller scale variations present in the data set, a FORTRAN program was developed that evaluated each independent hydraulic conductivity estimate in terms of the available surrounding estimates. When this program is executed, each K value was considered in conjunction will all other K values present within a user-specified radius, and the geometric mean of the available K values calculated. This geometric mean value is then assigned as the representative regional K value for that location. The radius used in this analysis was 10,000 meters, or approximately 6 miles. The point values obtained by this process were then kriged to develop a hydraulic conductivity distribution across the model domain. The aquifer transmissivity at each model node within each model layer was then computed at the geometric mean K values at that node times the thickness of the model layer. Insufficient data were available to attempt to subdivide the data set into depth varying K distributions and it was therefore assumed that the computed mean K values were representative of the major aquifer units in all model layers. Effectively this approach averages the aquifer K values at a given location. In reality, there is certainly vertical heterogeneity present in the Sacramento Valley aquifer system. However any inaccuracies in the assumed vertical distribution of K values will result primarily in local scale errors in computed vertical gradients. In the extremely heterogeneous aquifer system of the Sacramento Valley, it is the distribution of total aquifer transmissivity, along with the imposed water budget boundary conditions, that determine the regional distribution of hydraulic head. The efficacy of this approach at replicating the observed transient water level fluctuations across the valley will be demonstrated in the calibration section discussion below. The final distribution of hydraulic conductivity used in the SACFEM model is shown on Figure 8-4.

Model Calibration

Calibration Approach. The calibration approach used to develop the modeling tool described herein was significantly influenced by the resources available to fund the project. While a fully transient calibration approach, wherein the model is used to replicate groundwater levels and flow conditions throughout some period of record would be the more desirable approach, the resources were not available to fund such an effort. Instead, a more limited steady-state calibration approach was implemented. In a steady-state calibration process, the monthly water budget components for a selected period are averaged, and the model is calibrated to both average groundwater levels and stream discharges that occur during the calibration period. The calibration period selected for this effort was calendar year 2000. Calendar year 2000 was selected because it is the most recent year where water budget information is available that was characterized by average hydrologic conditions. A calendar year instead of a water year was used to facilitate the development of average groundwater elevation calibration targets. The available water-level data were obtained from DWR, and much of that data are collected in the spring and the fall. If a water year was used, the cut-off between water years is the end of September, which coincides with the mid-point of the fall sampling event. The result would be that when average groundwater elevation values were calculated, some of the measurements would be from October of the previous year and some would be from September of the subsequent year, which would introduce error in the data set, especially if the year types were different. The use of a calendar year eliminates this potential for error.

While a rigorous transient calibration was not possible as part of this effort, because the model was being used to simulated transient operation of conjunctive water management projects, simulated transient groundwater elevations were compared to observed groundwater elevation hydrographs from a collection of monitoring wells located throughout the model domain. The period of record over which the transient analysis was performed was water years 1982 through 2003. Therefore, simulated and observed transient groundwater elevations were compared over this period as well.

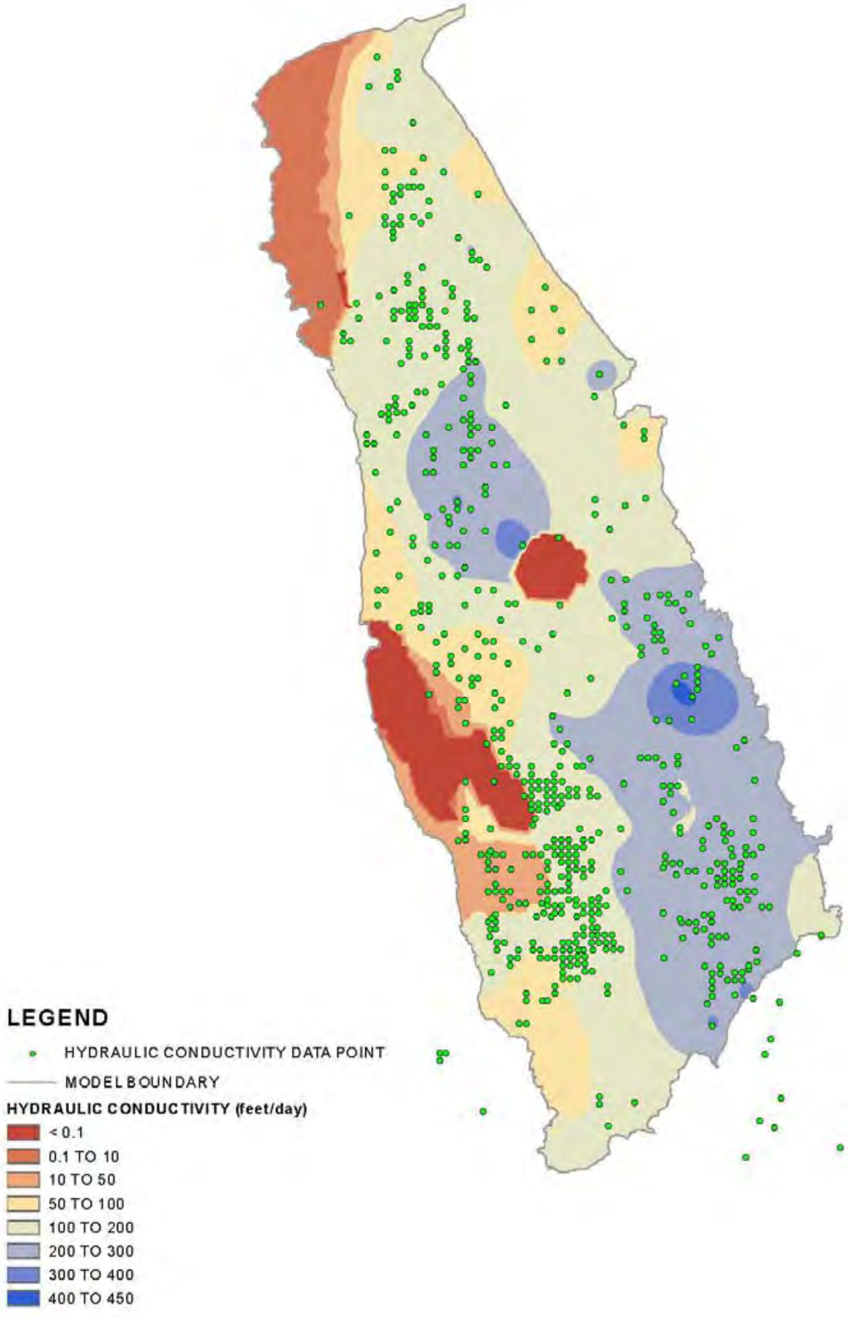


FIGURE 8-4
SACFEM HYDRAULIC CONDUCTIVITY DISTRIBUTION
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL
INVESTIGATION MODELING REPORT

Steady-State Calibration Targets. Several quantitative and qualitative calibration targets were used in the calibration process. These calibration targets are as follows:

- Average year 2000 groundwater elevations (257 wells used as calibration targets)
- Areas of gaining and losing streams (approximate)
- Approximate water budget quantities (order of magnitude comparison as no accurate estimates are available)
- Approximate calibration to transient groundwater levels measured between water years 1982 and 2003

Water Budget Modification. During the calibration process, it was anticipated that some adjustment to the water budget components computed using the previously described methodology would be necessary to obtain an acceptable degree of calibration. A water budget analysis performed on the raw input data provided by the root zone model, combined with simulated groundwater heads from model runs using that deep percolation data, suggested that the prescribed deep percolation rates in the northern (Red Bluff) and southern (Davis/Woodland) areas were too high. Deep percolation rates were reduced in these areas, resulting in a significant improvement in calibration residuals. To run the model is a transient mode, it was also necessary to make similar adjustments to the prescribed transient monthly deep percolation rates obtained from the root zone model. This was accomplished by computing the percent reduction in deep percolation that was required at each model node to obtain an acceptable steady-state calibration. It was then assumed that these same nodal reduction percentages were applicable to the monthly deep percolation estimates throughout the transient simulation period. While no rigorous transient calibration was performed, simulated groundwater levels over the 1982 though 2003 transient simulation period were compared to hydrographs of observed data at several locations across the model domain.

Steady-State Calibration to Year 2000 Groundwater Elevations. A graphical measure of the state of calibration is to develop a scattergram that plots the simulated versus the measured groundwater elevation at each target calibration well. A plot of this type is shown on Figure 8-5. A perfect fit between simulated and observed groundwater elevations would plot as a 45 degree line (slope = +1.0, Y-intercept=0). As can be seen on Figure 8-5, the simulated heads generated by the SACFEM model show good agreement between simulated and observed groundwater levels. This implies that the model is providing accurate estimates of the steady state groundwater elevations and flow directions that exist in the vicinity of the potential project sites evaluated under this conjunctive water management evaluation program.

Another quantitative measure of calibration that is commonly used is to calculate the root mean square error (RMS) divided by the range of observations. As a rule of thumb, a well calibrated regional model will have an RMS/range of less than 10 percent, and a well calibrated local scale mode will have an RMS/range of less than 5 percent. The RMS/range of the steady state calibration presented here is 4.6 percent, well below the 10 percent criterion.

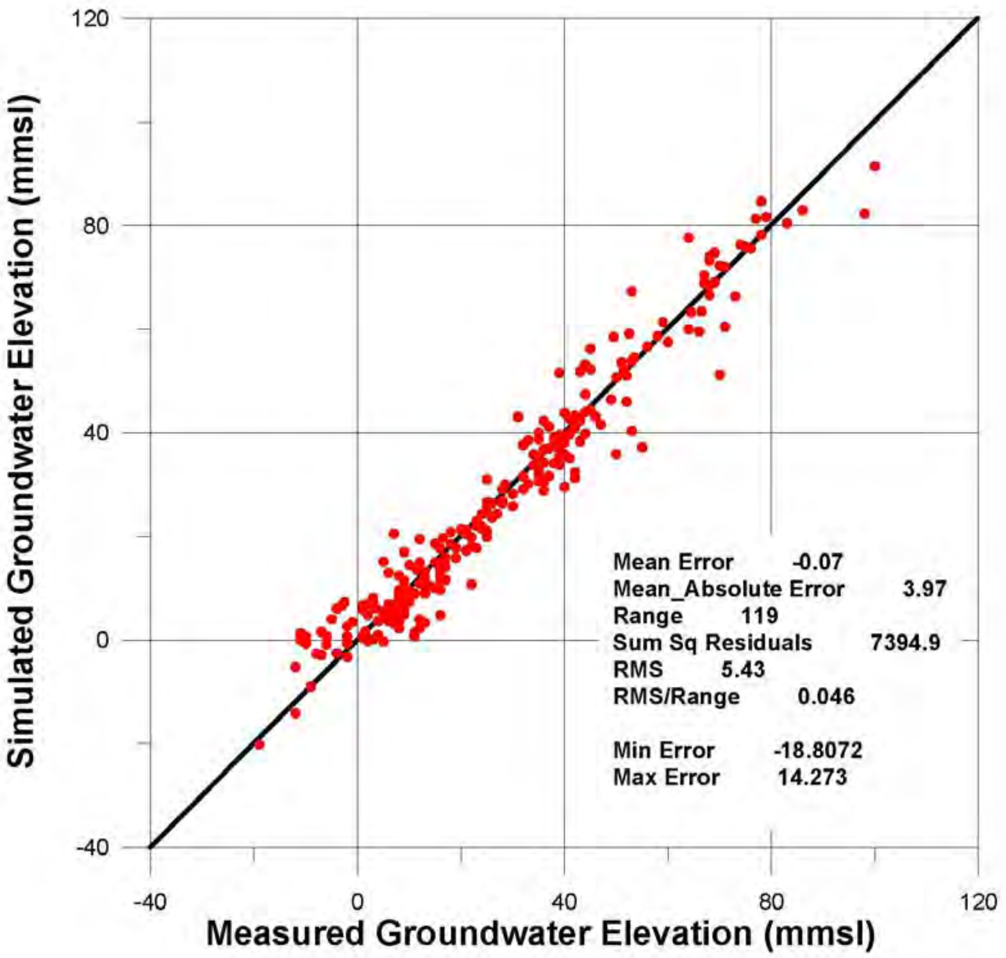


FIGURE 8-5
SACFEM CALIBRATION SCATTERGRAM
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Calibrations to Gaining and Losing Stream Segments. In the Sacramento Valley, a further qualitative calibration target is the identification of stream segments that are gaining flow through groundwater discharge versus losing flow to groundwater recharge. While the exact distribution of stream reaches that gain or lose flow due to surface water/ groundwater interaction are not fully delineated, and this relationship changes over time with fluctuating groundwater levels and stream stages, a general pattern can be observed. The major trunk streams such as the Sacramento, Feather, and American Rivers tend to gain flow, especially in their lower reaches, while the smaller upper tributaries near the basin margin tend to lose flow to the groundwater system. The stream reaches predicted by the model to gain or lose flow to the groundwater aquifer are shown on Figure 8-6. The pattern predicted by the calibrated groundwater flow model is reasonably consistent with the generally accepted pattern described above. The distribution shown on Figure 8-6 should be considered an average condition with greater stream lengths gaining groundwater during wet periods with higher groundwater levels and greater stream lengths losing water to the aquifer system during dry periods with lower groundwater levels.

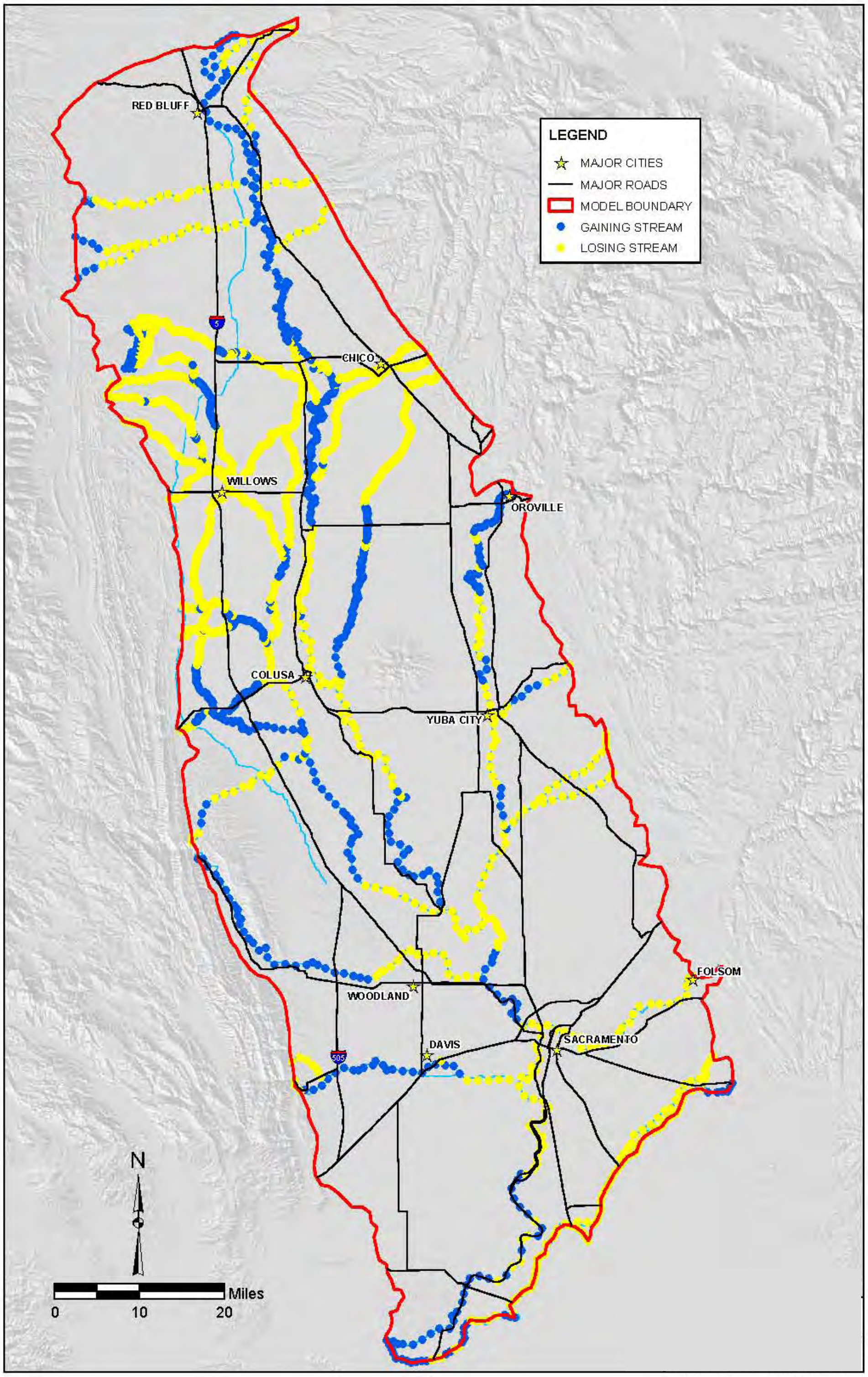


FIGURE 8-6
SIMULATED GAINING AND LOSING STREAM REACHES
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Calibration to Steady-State Water Budget. The magnitude of the water budget components derived from the steady-state calibration run are summarized in Table 8-1. While exact comparative estimates are not available for most of these components, rough estimates are available. For example, the 2000 calibration simulation estimates a combined 2.5 million acre-feet (ac-ft) of groundwater pumping within the model domain, which agrees reasonably well with the generally accepted value of between 2.5 million and 3 million ac-ft of groundwater withdrawal in an average year. Similarly, while no independent estimates of the quantity of groundwater that discharges to the Sacramento River are available, the average simulated value of 975 cubic feet per second (cfs), which represents approximately 2 to 4 percent of mean annual flow measured at the Freeport gauge, seems reasonable.

TABLE 8-1
Average Annual or Year 2000 SACFEM Water Budget Summary
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	ac-ft	cfs
Recharge		
Deep Percolation of Precipitation	1,398,461	1,932
Deep Percolation of Applied Water	865,131	1,195
Mountain Front Recharge	495,507	684
Seepage from Streams to Groundwater	816,848	1,128
Total Recharge	3,575,947	4,939
Discharge		
Agricultural Pumping	2,417,506	3,339
Urban Pumping	451,507	624
Groundwater Discharge to Streams	705,999	975
Total Discharge	3,575,012	4,938

Preliminary Transient Calibration. While the SACFEM model has not undergone a rigorous transient calibration, a comparison of simulated and observed groundwater elevations from Water Year 1982 through 2003 was performed to assess the performance of the model at simulating historic groundwater elevation trends. This step was necessary because the SACFEM model is being used to forecast the performance of various conjunctive water management projects during the 1982 through 2003 period, and it was necessary to determine the accuracy of the model at replicating the transient groundwater elevations that occurred over that period. The ability of the model to match observed transient heads is also an indication of the accuracy of the assumed transient water budget components being used in the model. The period 1982 though 2003 was used because it includes wet periods, such as the winter of 1983, and dry periods, such as the 1988 through 1992 drought. Using a climatic period of this type allows assessment of the effects of highly variable climatic conditions on conjunctive water management project operations and subsequent effects on groundwater levels and stream flows.

The accuracy of the model running in transient mode was assessed using two different methods. The first was to evaluate the ability of the SACFEM model to replicate the results of the final steady-state calibration run within a longer transient simulation. This was done by running the transient model using a monthly time step from water year 1982 though 2003, retrieving the simulated monthly head values for calendar year 2000, and averaging them to obtain a data set that should theoretically match the steady-state calibration data. The comparison of the simulated calendar year 2000 steady-state heads with the head values obtained by averaging the simulated monthly head values obtained from the transient simulation over the same period is shown on Figure 8-7. It is clear from this figure that the average calendar year 2000 heads computed from the results of the transient simulation almost exactly match the simulated steady-state heads obtained from the final calibration run. This suggests that after running the SACFEM model for 19 years (1982 though 2000) using estimates of the historic transient monthly water budget stresses, the model is still capable of providing a very accurate calibration to the year 2000 conditions.

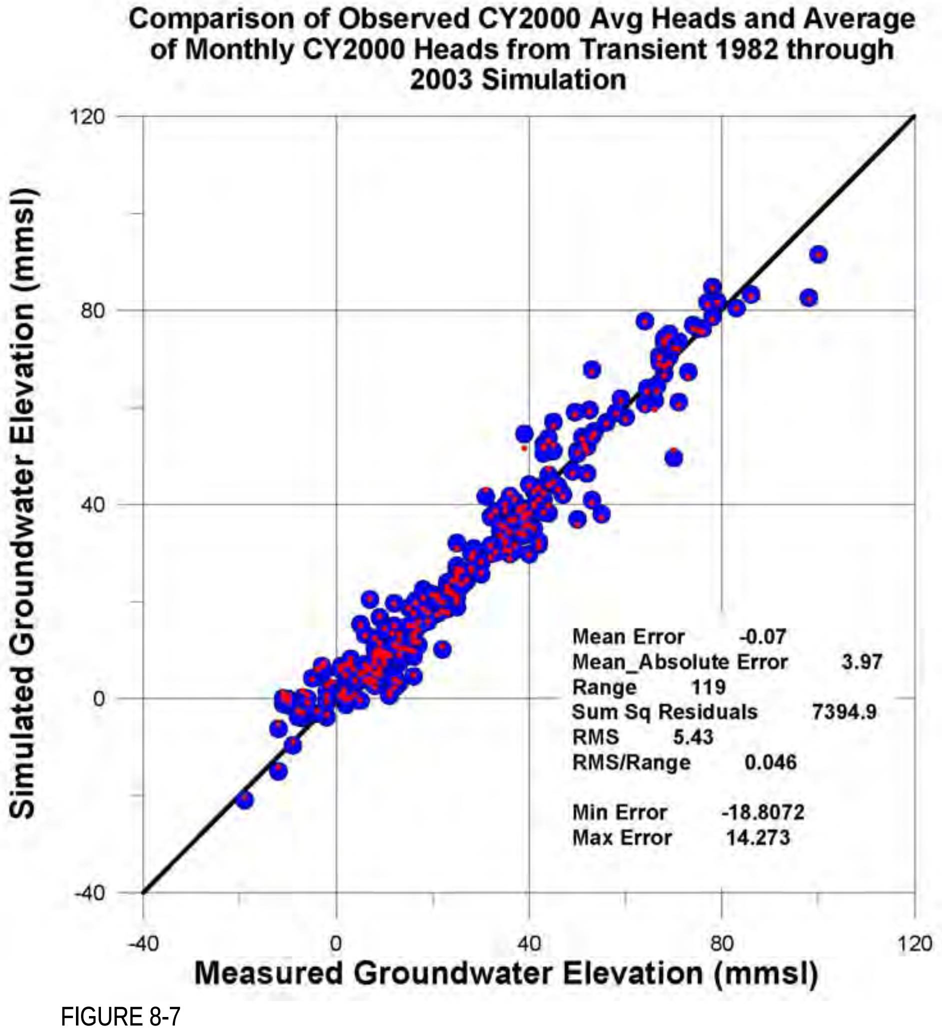


FIGURE 8-7
REPLICATION OF STEADY-STATE CALIBRATION HEADS WITHIN A 23 YEAR TRANSIENT SIMULATION
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

The second method used to assess the accuracy of the SACFEM model of simulating transient groundwater elevations was to compare simulated monthly groundwater elevations with measured groundwater elevations in monitoring wells over this same 1982 though 2003 period. These comparisons are shown on Figures 8-8 through 8-15. These results suggest that in most cases, the model provides a fairly accurate depiction of transient groundwater elevations throughout the time period evaluated. Several of the hydrographs show differences between the simulated and measured heads, but in each case the trends of both data sets are similar but displaced by several feet. It is likely that small adjustments in water budget fluxes or aquifer properties in those areas will improve agreement.

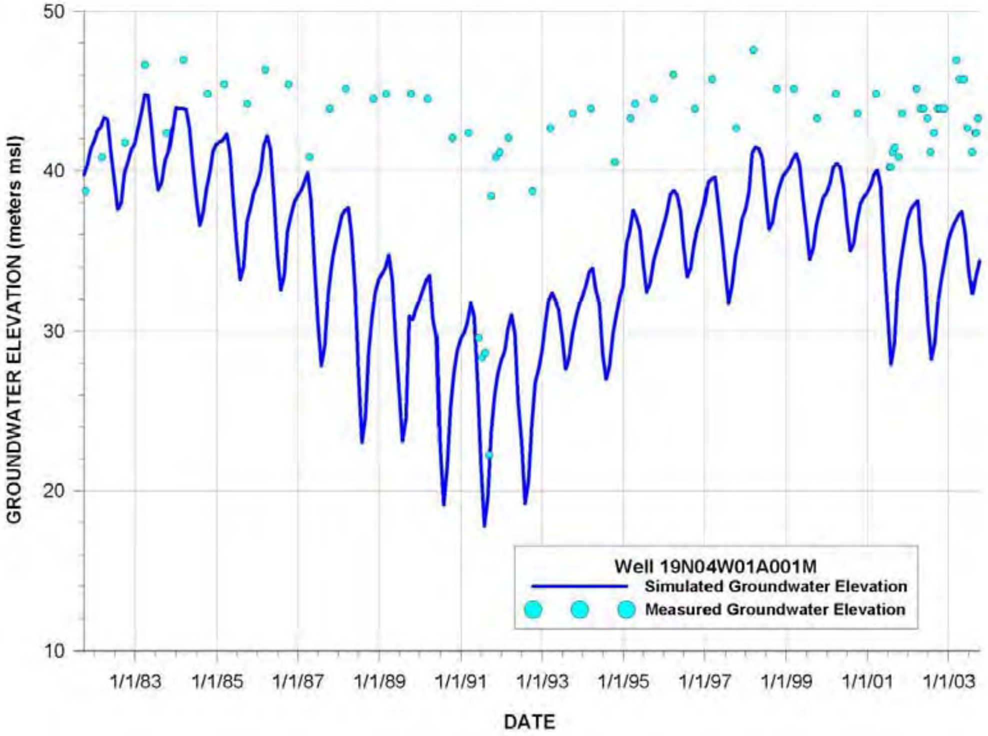


FIGURE 8-8
TRANSIENT CALIBRATION COMPARISON: WELL 19N04W01A001M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

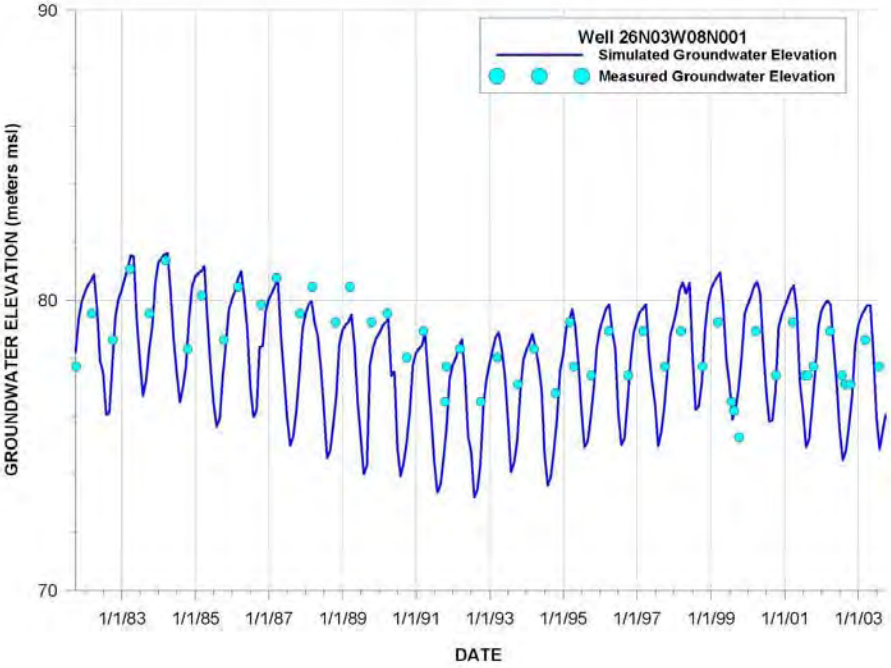


FIGURE 8-9
TRANSIENT CALIBRATION COMPARISON: WELL 26N03W08N001
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

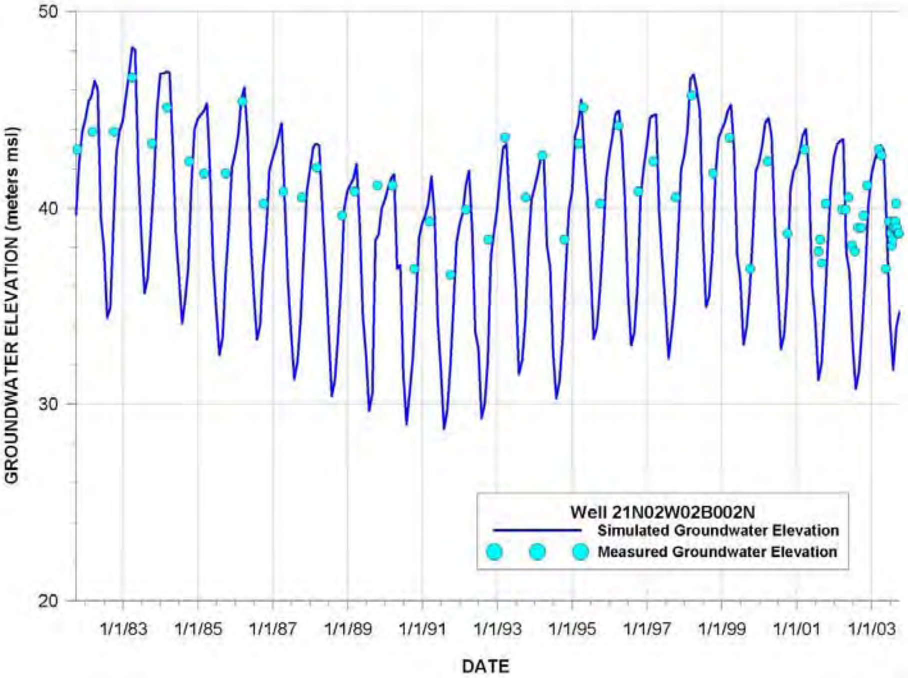


FIGURE 8-10
TRANSIENT CALIBRATION COMPARISON: WELL 21N02W02B0020N
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

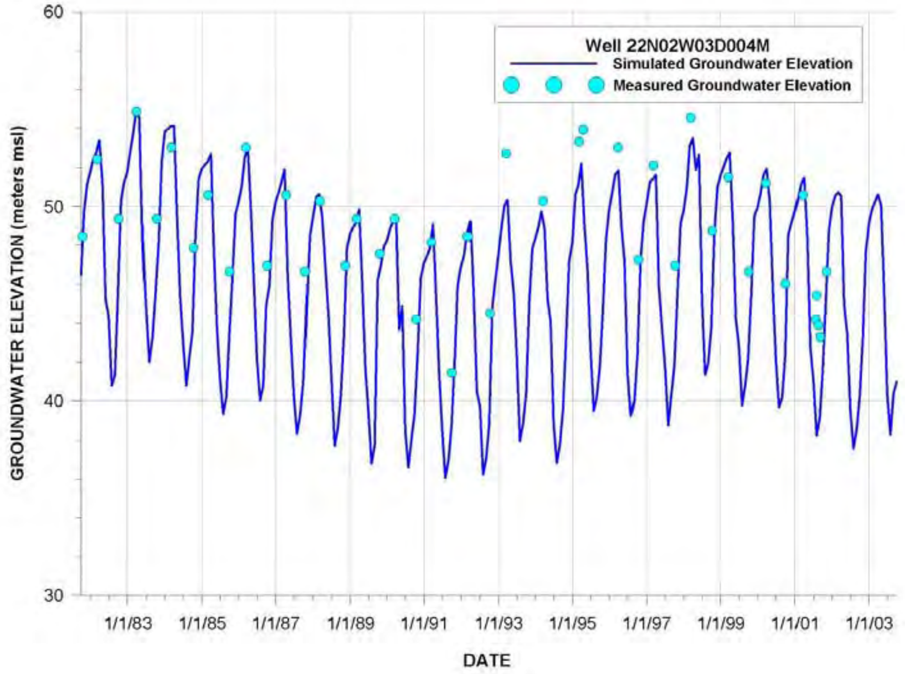


FIGURE 8-11
TRANSIENT CALIBRATION COMPARISON: WELL 22N02W03D004N
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

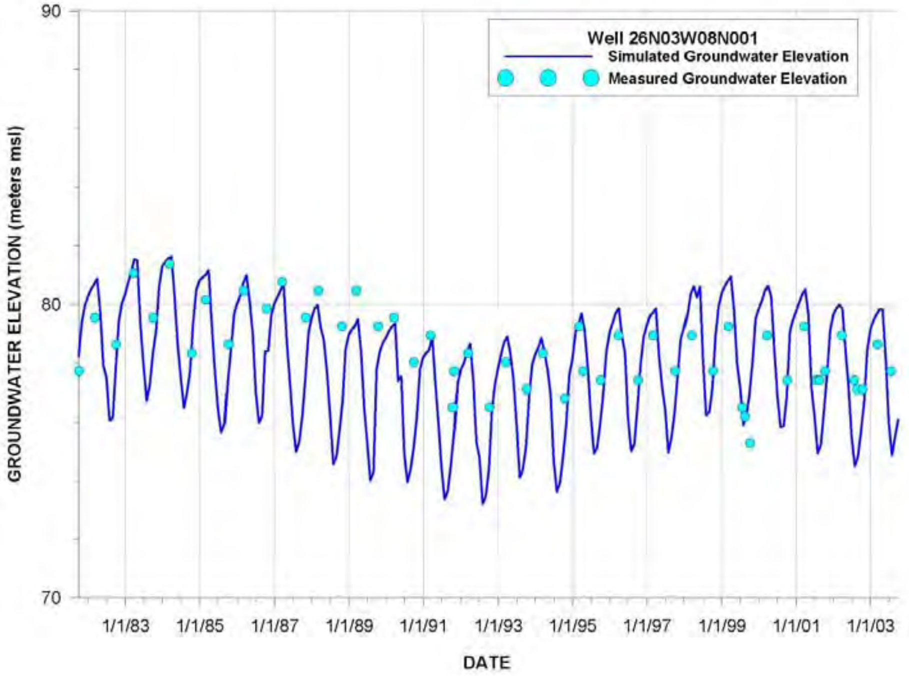


FIGURE 8-12
TRANSIENT CALIBRATION COMPARISON: WELL 26N03W08N001
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

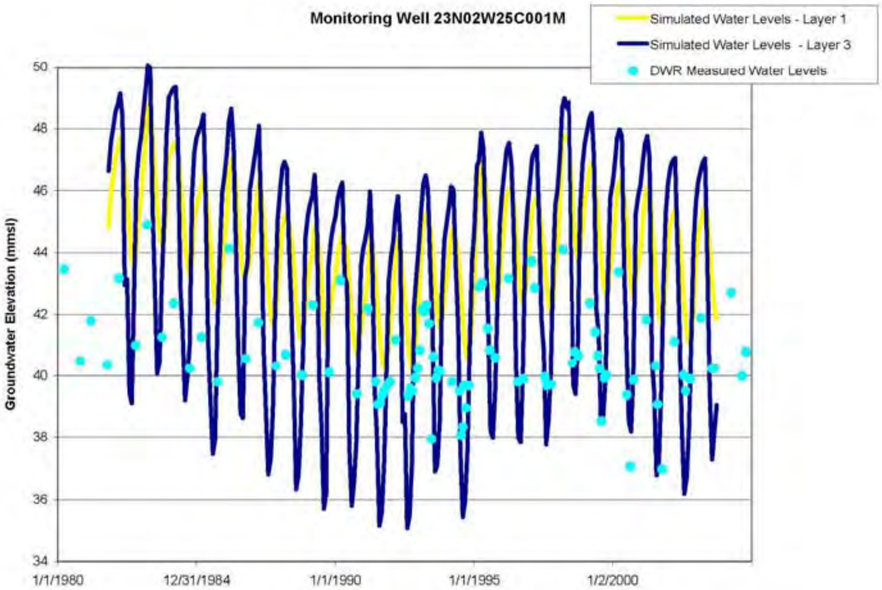


FIGURE 8-13
TRANSIENT CALIBRATION COMPARISON: WELL 23N02W25C001M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

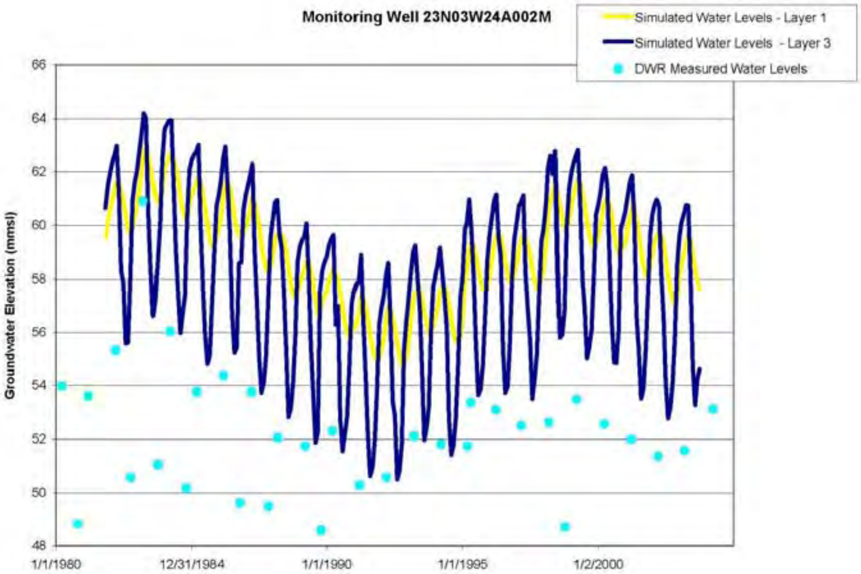


FIGURE 8-14
TRANSIENT CALIBRATION COMPARISON: WELL 23N03W24A002M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

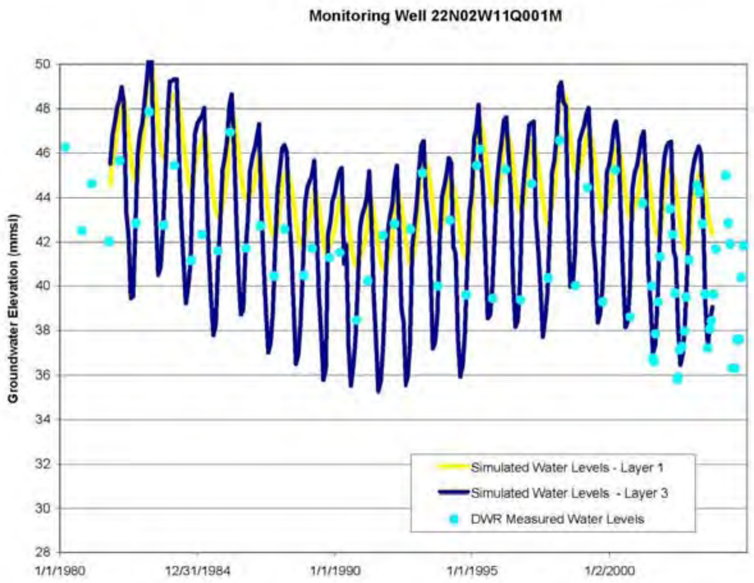


FIGURE 8-15
TRANSIENT CALIBRATION COMPARISON: WELL 22N02W11Q001M
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

SECTION 9

Surface Water Model

Effective analysis of conjunctive management projects and operations requires simulation of both the surface and groundwater systems. As described above, conjunctive management operations for this project are closely related to surface reservoir operations and conditions throughout the CVP and SWP. Therefore a surface water model that includes CVP and SWP reservoir operations and conditions was developed to evaluate conjunctive management projects.

9.1 Modeling Approach

The best tool currently available for planning level analyses of the CVP/SWP system is the CalSim II model, developed jointly by DWR and Reclamation. CalSim II is a planning model designed to simulate operations of CVP and SWP reservoirs and water delivery system, flood control operating criteria, water delivery policies, instream flow and Delta outflow requirements, and hydroelectric power generation operations. CalSim II is the main systemwide hydrologic model being used by DWR and Reclamation to conduct planning and impact analyses of potential projects.

CalSim II is a simulation by optimization model. The model simulates operations by solving a mixed-integer linear program to maximize an objective function for each month of the simulation. CalSim II was developed to simulate the operation of the CVP and SWP for defined physical conditions and a set of regulatory requirements. The model presently simulates these conditions using 82 years of historical hydrology from water year 1922 through 2003. CalSim II simulates regulatory conditions specified in State Water Resources Control Board (SWRCB) Decision 1641 (D-1641); the Central Valley Project Improvement Act b(2), including non-discretionary and discretionary actions; and limited water transfer operations.

CalSim II is a complex optimization model that can give surprising, unintended results when used to simulate complex operations. Additionally, runtimes for CalSim II models are typically several hours, making it inappropriate for use in gaming sessions and for rapid evaluation of many different scenarios.

The approach used for this project is to rely on CalSim II to depict CVP/SWP operations and system conditions and then model incremental changes in CVP/SWP operations that reflect possible conjunctive management projects. The result of this approach is a surface water model of the CVP/SWP system that layers conjunctive management operations for use in gaming sessions to quickly investigate numerous scenarios and operations, and can be used to test sensitivities and tradeoffs associated with certain key assumptions. The surface water model was designed to be easily adapted for use with various CalSim II simulations.

9.2 System Baseline Assumptions

A CalSim II simulation of the existing level of development (approximately 2004), regulatory conditions, and resulting operation of the CVP and SWP is the basis for surface water modeling. This simulation was developed by the Common Assumptions Project to provide a generally accepted model baseline for use in CALFED surface storage investigations. Key assumptions for the baseline CalSim II simulation are provided in Appendix A.

The existing level of development was used, as opposed to a future level of development, because of the need for consistency in land use data used in the surface water groundwater models. Existing level of development GIS land use data were used in the development of the surface water budgets for the groundwater model. Existing level of development information is also less speculative as to how land use may change in the coming decades. Simulation of a future level of development would require assumptions on future land use and the spatial distribution of that land use throughout the Sacramento Valley.

9.2.1 Surface Water Model Operations

The surface water model simulates operations of conjunctive management projects and their interaction with CVP and SWP reservoirs to meet project objectives (satisfying presently unmet agricultural water demands and targeted environmental flows and durations) based on results of a CalSim II simulation of existing system operations. The following sections define and describe individual aspects of model operation. This section concludes with a description of how the individual pieces interact to simulate system operations with conjunctive management.

9.2.2 Environmental Objectives

The surface water model simulates conjunctive management operations to increase water supply within the Sacramento Valley. The additional water supply can be used to meet a combination of agricultural water demands and environmental flow objectives. Environmental flow objectives were developed by National Heritage Institute staff and documented in *Developing Ecologically Based Flow Targets for the Sacramento and Feather Rivers* (Cain and Monohan, 2008). Different flow objectives were developed for the Sacramento and Feather Rivers.

All flow objectives are simulated as all-or-nothing thresholds, meaning the model will release water to meet the flow objective only if the full target flow can be sustained for the specified duration. As discussed in the NHI report, environmental objectives are based on the magnitude and duration of flows required to replicate certain ecological and geomorphic processes.

Environmental objectives are specified and prioritized by water year type. The Sacramento River Water Year Type Index (Sacramento River Index), sometime referred to as the 40-30-30 Index, is used to classify each year as either wet, above normal, below normal, dry, or critical.

Geomorphic

Geomorphic releases are short-duration, high-flow events for the purpose of sediment transport, channel migration, and flood plain processes, such as inundation and fine sediment transport. Geomorphic releases are targeted from March through April and are only required to last several hours. The surface water model simulates geomorphic events lasting one day due to the ramping requirements when making these large releases from reservoirs. Table 9-1 presents geomorphic flow objectives for Sacramento and Feather Rivers.

TABLE 9-1
Geomorphic Flow Objectives for Sacramento and Feather Rivers
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Sacramento River Index	Sacramento River (cfs)	Feather River (cfs)
Wet	105,000	50,000
Above Normal	85,000	35,000
Below Normal	65,000	20,000
Dry	35,000	10,000

No objective specified in critical year types.

Riparian Establishment

The purpose of riparian establishment flows is to recruit and grow cottonwoods in the riparian areas along the rivers. Riparian establishment flows are designed to assist in several phases of early cottonwood growth including seedbed preparation, seed germination, and seedling growth. These flows also create periodic large-scale disturbances of the riparian zone. Riparian establishment objectives (see Figure 9-1) are specified for the period of mid-April through mid-June to coincide with the cottonwood reproductive cycle. Riparian recruitment flows are large-magnitude flows for extended periods of time and are typically only possible during years of above average runoff. Therefore these objectives are only specified in years classified as wet or above normal by the Sacramento River Index.

Figure 9-1 illustrates the shape of the of riparian establishment objectives. The objective begins with a high-flow event held for a period of 5 days followed by a 60-day recession limb when the target each day is 5 percent less than the previous day’s target. Table 9-2 summarizes the objectives for both the Sacramento and Feather Rivers.

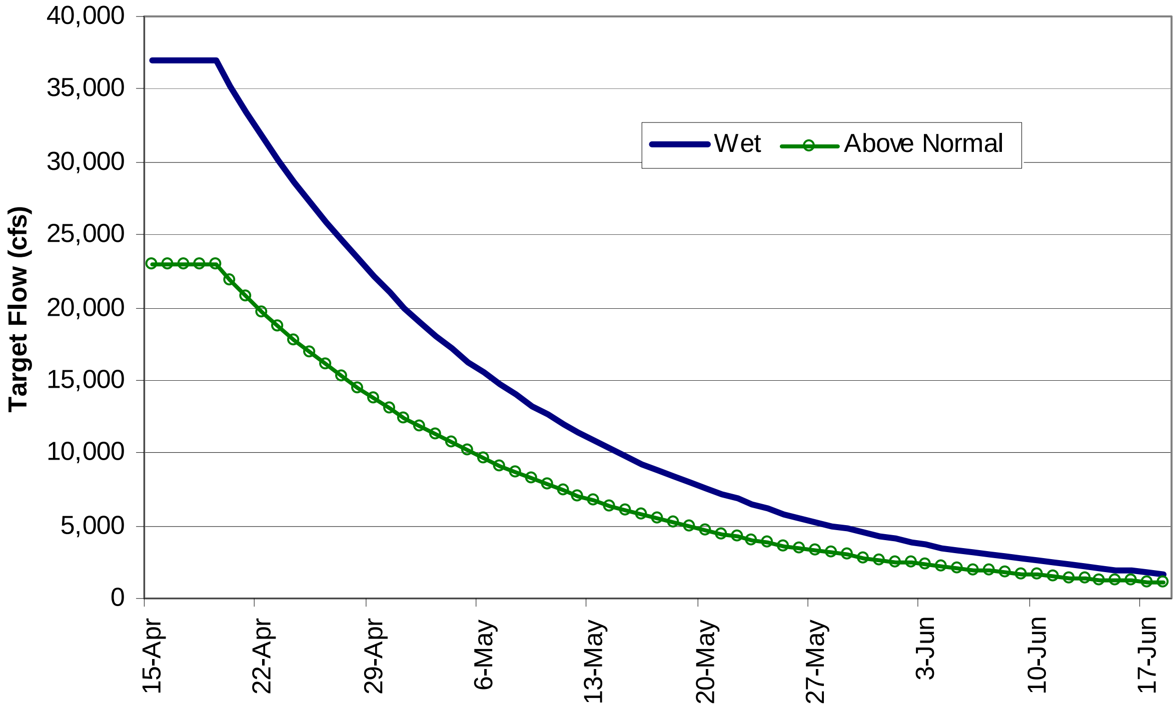


FIGURE 9-1
SACRAMENTO RIVER RIPARIAN ESTABLISHMENT OBJECTIVE
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

TABLE 9-2
Riparian Establishment Objectives
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Sacramento River		**Feather River**	
Sacramento River Index	**5-day Flow (cfs)**	**Recession Rate**	**5-day Flow (cfs)**	**Recession Rate**
Wet	37,000	5%	12,000	5%
Above Normal	23,000	5%	10,000	5%

Note:

No objective specified in below normal, dry, or critical year types

Spring Pulse

Spring pulse flows are designed to simulate a portion of the historic unimpaired runoff of the river to help create suitable flow conditions and temperatures for Chinook salmon migration. These flows also are designed to help maintain and recruit spawning habitat and avoid scour when eggs are in redds. Spring pulse flow targets are specified in all but critical year types, though the magnitude and duration of the target is reduced in years with less runoff. Tables 9-3 and 9-4 summarize the spring pulse objectives.

TABLE 9-3
Sacramento River Spring Pulse Objective
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Sacramento River Index	Flows (cfs) by Date					
	3/15-3/31	**4/1-4/14**	**4/15-4/30**	**5/1-5/14**	**5/15-5/31**	**6/1-6/14**
Wet	14,000	14,000	14,000	14,000	14,000	8,500
Above Norm	12,500	14,000	14,000	14,000	8,500	
Below Norm	12,500	12,500	12,500	8,500		
Dry	10,000	12,000	12,000	8,500		

Note: No objective specified in critical year types

TABLE 9-4
Feather River Spring Pulse Objective
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Sacramento River Index	Flows (cfs) by Date					
	3/1-3/14	**3/15-3/31**	**4/1-4/14**	**4/15-4/30**	**5/1-5/14**	**5/15-5/31**
Wet	8,000	12,500	12,500	11,000	6,000	4,000
Above Norm	6,500	6,500	10,000	10,000	5,000	3,000
Below Norm	3,200	3,200	8,000	8,000	3,200	
Dry	2,700	2,700	5,500	5,500	2,700	

Note: No objective specified in critical year types

Flood Plain Inundation

Inundation of the Sutter and Yolo Flood Bypass channels is another environmental objective. It is assumed for this study that the weirs that currently block flow into the bypasses below certain river stages can be modified to allow inundation at lower river stages and flows. Inundation of the flood bypasses provides rearing habitat for juvenile salmonids. These inundation flows are targeted to correspond with outmigration of salmonids in the spring months and designed to last for 45 days. Flood plain inundation flows can be set for one of three different time-periods in the surface water model: February 15 to March 30, March 1 to April 15, or March 15 to April 30. Table 9-5 presents flood inundation objectives for Sacramento and Feather Rivers.

TABLE 9-5
Flood Plain Inundation Objective for Sacramento and Feather Rivers
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Sacramento River Index	Sacramento River at Fremont Weir (cfs)
Wet	45,000
Above Normal	35,000
Below Normal	35,000
Dry	35,000

Note: No objective specified in critical year types

Cold Water Pool Management

The surface water model includes an environmental objective of increasing the flexibility of cold water pool management. This objective increases cold water pool volume in subsequent years by reducing summer reservoir releases (thereby increasing storage) in the current year by the volume of groundwater being pumped. This volume of water is then held in the reservoir through the winter and can increase cold water pool in following years. This operation occurs in years when fall reservoir storage is forecasted to be low. Low fall storage levels reduce the chance that any water stored will spill during the subsequent winter. However, operators may not be able to reduce summer releases in these years and still meet temperature control criteria in the current year. For example, summer releases from Lake Shasta in 2008 were typically controlled by temperature control criteria, not downstream irrigation demands. Therefore, it would not have been possible to offset reservoir releases with groundwater pumping. The surface water model is able to show the times and volumes of water potentially available to meet the cold water pool management objective, but a more thorough analysis with temperature models is needed to further evaluate the feasibility of this operation.

9.2.3 Agricultural Water Supply Objectives

The surface water model simulates the unmet agricultural demand within the Sacramento Valley based on hydrology, the underlying CalSim II simulation of CVP and SWP operations, and user input. Unmet agricultural demands are estimated to provide an understanding of the ability of conjunctive management to increase Sacramento Valley water supplies. Unmet agricultural demands are simulated differently for the Sacramento and the Feather River systems.

Sacramento River

Unmet demands of CVP contractors within the Tehama-Colusa Canal Authority (TCCA) are used to represent additional demands on the Sacramento River. Members of the TCCA, including contractors supplied from the Corning Canal, hold agricultural service contracts for approximately 320 TAF of contract supply from the CVP. Annual allocations to CVP contractors are simulated in CalSim II based on forecasted reservoir inflows, reservoir storage conditions, and the ability to deliver water. Simulated allocations range from 0 to 100 percent of full contract supply. When simulated allocations are less than 100 percent, it is assumed that the difference between simulated allocations and full contract supply is an unmet agricultural demand within the TCCA.

Figure 9-2 illustrates the annual unmet agricultural demand as a function of simulated allocations to the TCCA for each year of the study.

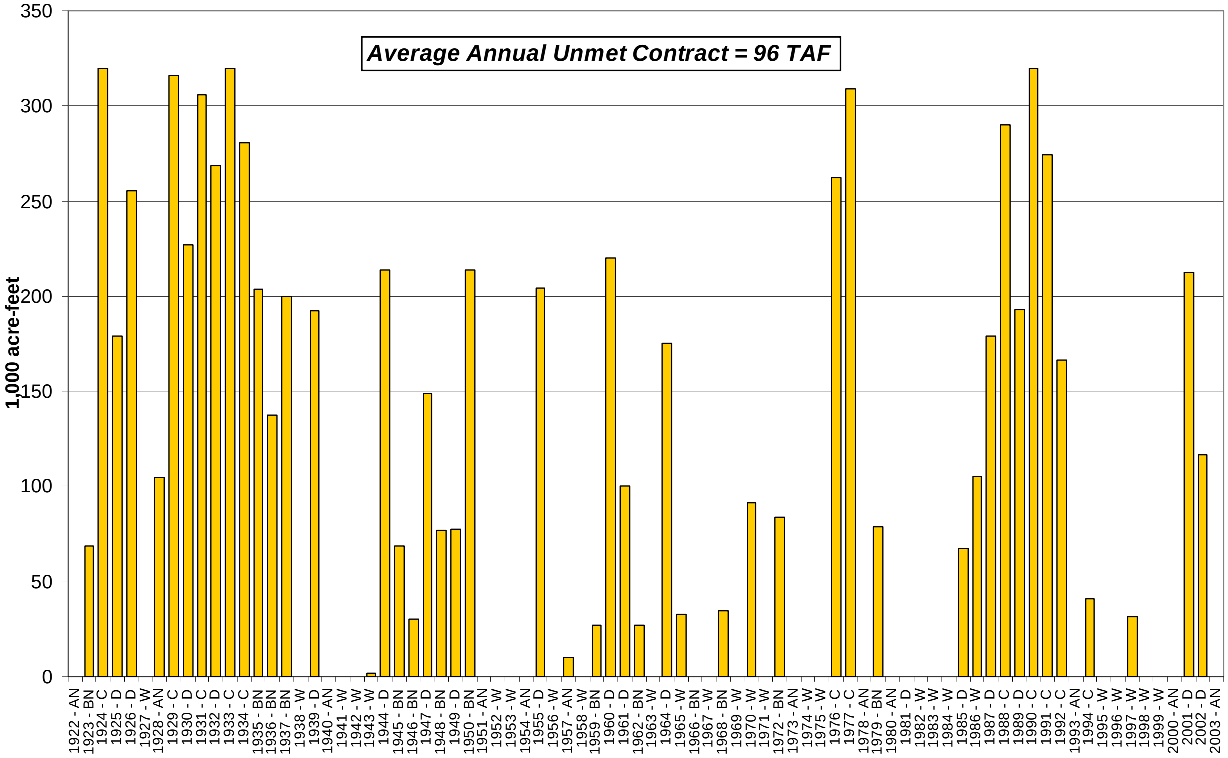


FIGURE 9-2
UNMET AGRICULTURAL DEMAND WITHIN TCCA
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

The annual unmet demand illustrated above is assumed to occur on a typical agricultural demand pattern during the irrigation season. The gaming model simulates conjunctive management operations and attempts to meet all or a portion of this demand when it occurs from reservoir release of project assets.

Feather River

The majority of SWP contractors on the Feather River system have reliable water supplies with the exception of a few small contractors. There are no existing SWP contractors with large, frequently unmet agricultural demands in the Butte Basin. Therefore a more general unmet agricultural demand is defined for the Feather River based on user input. Table 9-6 summarizes the assumed unmet agricultural demand that can be met from Feather River supplies in the surface water model.

TABLE 9-6
Assumed Unmet Agricultural Demand within the Feather River System
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Sacramento Valley Index	Unmet Agricultural Demand (TAF)
Wet	0
Above Normal	40
Below Normal	75
Dry	90
Critical	100

Figure 9-3 illustrates the annual volume of demand based on the assumptions in Table 9-6.

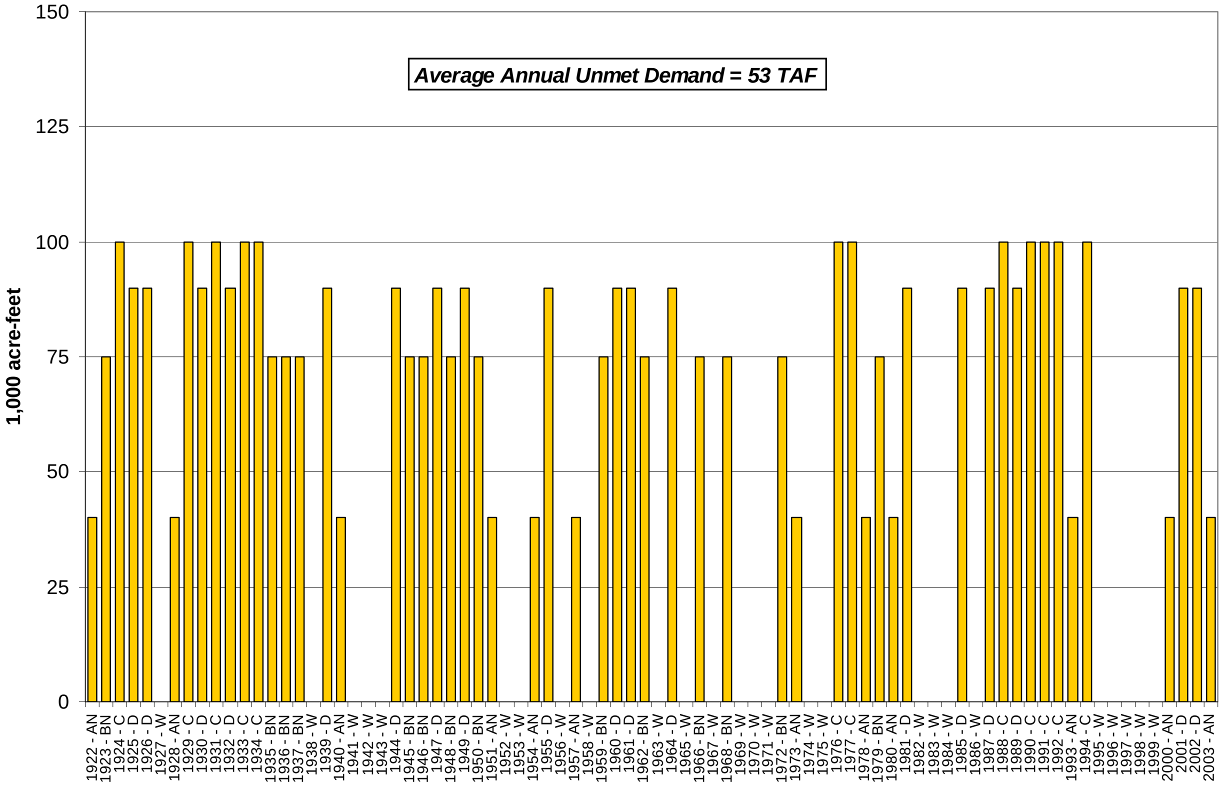


FIGURE 9-3
ASSUMED UNMET AGRICULTURAL DEMAND WITHIN FEATHER RIVER SYSTEM
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

9.2.4 Project Site Assumptions

Two project sites were selected for modeling. Project sites within GCID and the Butte Basin were simulated in the surface water model to determine the volume and timing of ground-water pumping and to better understand tradeoffs between groundwater pumping capacity and project benefits in the surface water system.

Each conjunctive management project site is defined in the model by several variables including maximum annual groundwater pumping capacity, monthly volumes of project pumping, and estimates of how pumping will affect stream-aquifer interactions. The estimated effects on stream-aquifer interaction were derived from iterative simulations between the surface and groundwater models.

The surface water model was developed to quickly evaluate a wide range of project pumping capacities and operations. Results of these sensitivity analyses (presented in later sections) led to evaluation of the following two different project pumping capacities or sizes: 1) 100 TAF in GCID and 50 TAF in Butte Basin, and 2) 200 TAF in GCID and 100 TAF in Butte Basin. Additionally, it was assumed that there would be no additional project pumping in years when surface water allocations are reduced in GCID or the Butte Basin. GCID's surface water allocations are reduced in years classified as "Shasta Critical" based on Sacramento River inflow into Shasta Reservoir. Feather River Settlement Contracts in the Butte Basin received reduced allocations under similar conditions on the Feather River.

Project Assets

Project assets are the volume of water that could potentially be made available through conjunctive management and the volume of additional water that could be released from CVP and SWP reservoirs to meet environmental flow targets or for additional agricultural water supply. Additional reservoir releases are possible because of the availability of groundwater pumping in the conjunctive management project, which serves as a "backstop" against drawing down reservoirs too far. Project assets are calculated each year considering reservoir storage conditions and available groundwater pumping capacity. A reservoir storage target table is used to determine how far operators may be willing to draw down reservoirs for different levels of available groundwater pumping capacity. Table 9-7 is an example for Shasta Reservoir that was a conjunctive management project in GCID with a maximum of 100 TAF of annual pumping capacity.

TABLE 9-7
Example Shasta Reservoir Storage and Project Assets
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

End of September Storage (TAF)	Project Asset (TAF)
Less than or equal to 2,400	0
Greater than 2,500	100

Table 9-7 shows that if end-of-September storage in Shasta Reservoir is forecasted to be less than 2,400 TAF, there are no project assets; therefore, no additional reservoir releases will be made. When forecasted end of September Shasta storage exceeds 2,500 TAF, additional reservoir releases up to the full 100 TAF of pumping capacity may be made to meet project objectives. The maximum project asset is the maximum annual pumping capacity because this represents the maximum backstop available to recover the reservoir in future years, if needed. The model interpolates if storage is between 2,400 and 2,500 TAF so that project operations do not draw Shasta Reservoir storage below 2,400 TAF. A conservative minimum end of September storage of 2,400 TAF was selected as a minimum to avoid any potential impacts.

Project assets also take into account any existing storage deficit, relative to baseline storage, in upstream reservoirs that may be carried over from project operations in previous years. Thus, the cumulative storage deficit over any series of years cannot exceed the annual groundwater pumping capacity of the conjunctive management project.

Water Cost

The surface water model compares environmental flow objectives with base flows that occur under existing system operations to determine additional reservoir releases necessary to meet each environmental objective. This additional release, calculated for the duration of the objective, is referred to as the water cost associated with meeting each environmental object. Water cost is expressed as a volume of water. Water cost for each objective is compared to available project assets to determine which objectives can be met. Figure 9-4 provides an example of water cost calculation for meeting a spring pulse objective.

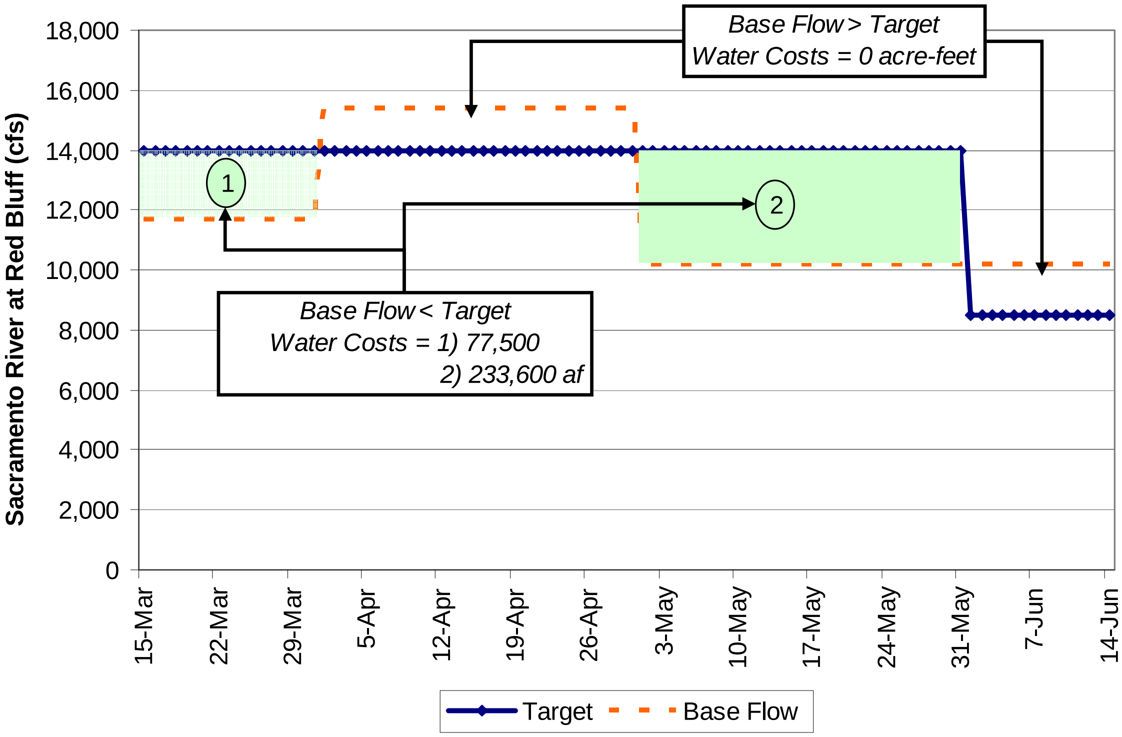


FIGURE 9-4
EXAMPLE WATER COST FOR MEETING SPRING PULSE OBJECTIVE
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

The water cost for meeting agricultural objectives is equal to the unmet agricultural demands for any year.

Prioritization

Environmental objectives are prioritized through a combination of user input and the frequency with which the various objectives are satisfied. Considering the frequency of when objectives have been satisfied places higher priority on objectives that have not been met in recent years relative to those that have. For example, if the spring pulse objective is typically the highest priority in an above normal year but was met in the previous year (either in the base condition or with a project release) it may be desirable to shift the highest priority to the flood plain inundation objective instead.

To implement this dynamic prioritization scheme that shifts the priority from one year to the next depending on year type and occurrence interval a user-specified relative priority value is combined with the number of years since an objective was last satisfied to determine the final priority of objectives each year.

Table 9-8 contains the relative priority matrix developed by the project team for use in the surface water model. Lower numbers are higher priorities.

TABLE 9-8
Relative Priority Matrix for Environmental Objectives
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Sacramento River			Both Rivers	Feather River		
Sacramento River Index	**Geomorphic**	**Riparian Recruitment**	**Spring Pulse**	**Flood Plain Inundation**	**Geomorphic**	**Riparian Recruitment**	**Spring Pulse**
Wet	10	2	10	10	10	2	10
Above Normal	15	6	2	4	15	5	2
Below Normal	2	99	1	3	2	99	1
Dry	5	99	2	90	5	99	2
Critical	80	99	1	90	80	99	1

Final priority is determined by subtracting the relative priority from the number of years since the objective was met and comparing the results for all objectives.

Table 9-9 provides an example prioritization calculation for a hypothetical wet year on the Feather River system.

TABLE 9-9
Example Prioritization of Environmental Objectives, Feather River, Wet Year
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Flood	Geo	Rip.	Spring
Years Since Met	6	1	4	25
Relative Priority	10	10	2	10
Final Priority	-4	-9	2	15

The objectives are prioritized by descending final priority scores, as follows: Spring Pulse, Riparian Recruitment, Flood Plain Inundation, and Geomorphic. In this example, because it had been 25 years since the spring objective had been met, Spring Pulse became the first priority objective, though its relative priority was lower than the Riparian Objective.

Decision Month

A decision must be made each spring to determine which objectives the model will attempt to meet that year. Several of the environmental objectives have variable start times and durations. To avoid always meeting the objective that starts earliest in the year or miss meeting an objective in hopes of satisfying a future objective, a user-specified decision month is used in the model. Project assets, water costs, and prioritization of environmental objectives are all determined during the decision month and results are used for operations that year. The decision month is used to determine what objectives the model will attempt to meet each year.

Agricultural Water Supply Objective

After determining which, if any, environmental objectives will be met from project assets the model calculates the remaining project assets available to meet any unmet agricultural demands. This operation wherein environmental objectives were met first and agricultural objectives second was used because environmental objectives are all-or-nothing thresholds, often with large water costs. In many years, all or a portion of project assets are available after making releases for environmental objectives. Simulations where agricultural water supply was prioritized first did not show significant increases in agricultural water supply deliveries, but significantly reduced the ability to meet environmental objectives. This analysis is presented in the section on sensitivity analysis.

Reservoir Release Logic

Figure 9-5 provides a flow chart of model decisions and operations for determining which objectives will be met from additional reservoir releases.

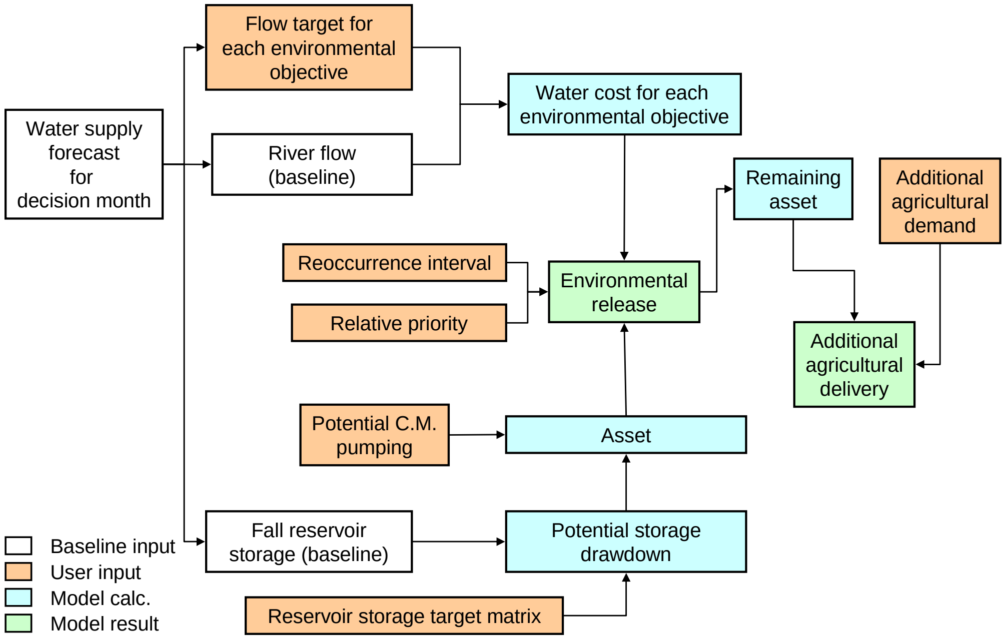


FIGURE 9-5
SURFACE WATER MODEL LOGIC FLOWCHART
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

The bottom of Figure 9-5 illustrates the steps associated with calculating project assets while the top illustrates the calculation of water costs and additional reservoir release. Assets and water costs are compared, according to the prioritized environmental objectives to determine any additional reservoir release for environmental objectives. Remaining assets and unmet agricultural demand are used to determine additional agricultural delivery from the reservoirs.

Groundwater Pumping Logic

Additional reservoir releases result in lower reservoir storage conditions relative to the baseline condition (without the conjunctive management project). Reservoir storage is refilled in the model from one of the following two sources: water that would have otherwise been released for flood control purposes or an increase in groundwater pumping to meet demands that otherwise would be met from the reservoir.

The surface water model simulates these operations by drawing down reservoir storages to make additional releases for project objectives and tracking the storage deficit relative to the baseline. In many instances storage deficits are refilled by water that would otherwise be released for flood control purposes (surplus surface water). Additional groundwater pumping is required when reservoirs are depleted prior to a series of dry years in which they do not fill. The surface water model uses fall reservoir trigger levels to determine when pumping is needed. These triggers are 2,400 TAF for Shasta Reservoir and 1,500 TAF for Lake Oroville. Therefore, if project operations result in reservoir storages below these levels pumping will occur to refill the minimum of any deficit caused by project operations or up to these levels.

Project pumping can be specified to occur over the summer season (May through August) the fall season (September through November) or a combination of both (May through November). Regardless of the selected season the total quantity of water to be pumped is spread evenly across the entire season to avoid turning pumps on and off and to reduce the number of groundwater production wells needed. Different seasons and pumping durations were selected to test the effects of pumping at different times and rates.

9.3 Surface and Groundwater Model Interaction

Evaluation of conjunctive management projects requires simulation of both surface water and aquifer systems. However, regional groundwater models with the needed level of refinement to adequately simulate pumping projects require run times that prohibit their use in gaming situations and for quickly evaluating multiple scenarios. Therefore, the surface water and groundwater model were used in an iterative fashion to simulate conjunctive management operations in both systems (see Figure 9-6).

An initial surface water model was developed to simulate project operations and develop the time series of groundwater pumping at each project site. Pumping time series were simulated in the groundwater model and results were reviewed, including changes in stream-aquifer interactions. These initial changes were used to develop response functions for use in the gaming model to quickly approximate changes in stream-aquifer interaction when simulating various conjunctive management operations. Response functions were used during the gaming sessions and when conducting tradeoff analyses to determine the final project scenarios. Pumping time series from the final project scenarios were then provided to the groundwater model for final simulation and resulting changes in stream-aquifer interactions associated with the pumping schedules were input back into the final surface water simulations.

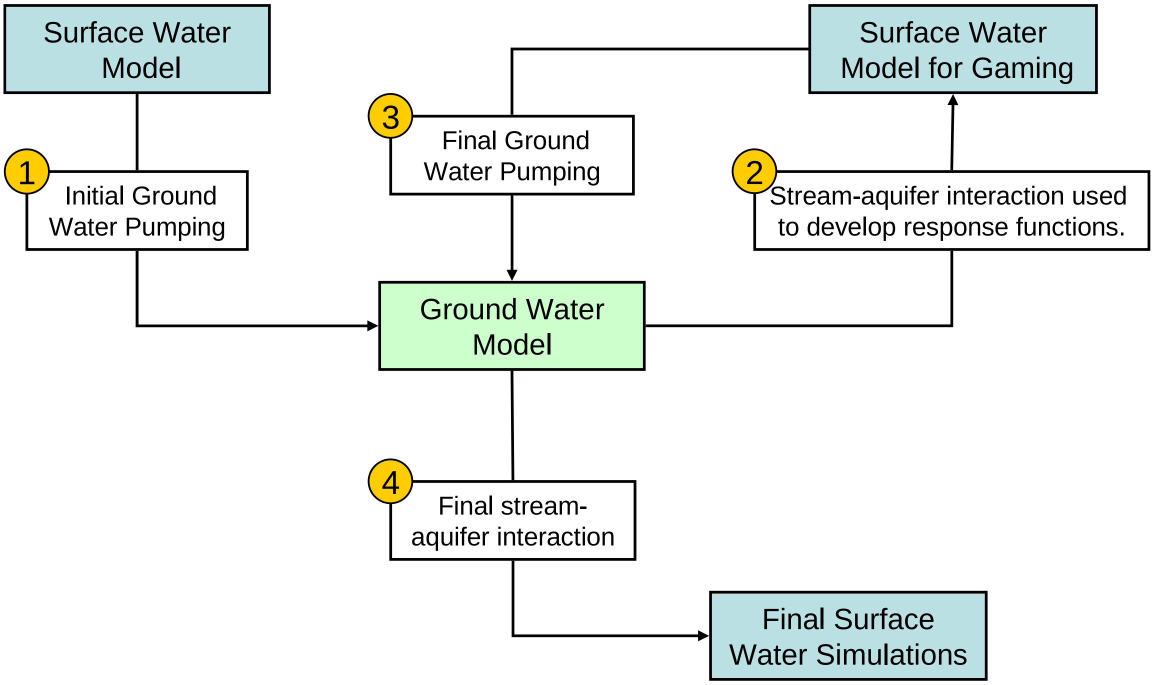


FIGURE 9-6
SURFACE WATER AND GROUNDWATER MODEL INTERACTION
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

SECTION 10

Level of Analysis

Technical analyses were performed at a planning level to help prove concepts and define conjunctive management projects and operations. Analyses were conducted for general projects, locations, and operations. More specific and refined analyses may be required as specific projects are defined. Most analysis was conducted in a comparative, rather than absolute, manner and results must be interpreted as such.

Additionally, mathematical modeling tools typically report results at a level of precision that exceeds their level of accuracy. For example, planning-level surface water models may provide estimates of water supply accurate to within a range of several thousand acre-feet, but results with a precision down to an acre-foot. Surface water model results presented in subsequent sections are generally rounded to the nearest 1,000 acre-feet. Groundwater draw down is reported in approximately 10-foot increments, and changes in stream-aquifer interaction are reported to the nearest cfs. Results are reported to these levels of precision for comparison with results from other scenarios. Planning-level modeling tools used in this analysis are not necessarily accurate to this level.

SECTION 11

Project Scenario Results

The following section presents results from four different project scenarios. All scenarios are based on two conjunctive management projects, one in GCID and the other in the Butte Basin. Surface water modeling results are presented first and include the ability to meet environmental and agricultural objectives, the resulting effects on reservoirs, and how reservoirs are refilled with the capture of surplus surface water and conjunctive management pumping.

Groundwater model results are presented after surface water model results. Groundwater model results include plots of peak aquifer drawdown and changes in stream-aquifer interaction. For each scenario, the groundwater model was used to evaluate two different well fields. The first well field option uses existing wells screened in the current aquifer producing zones. The second well field simulates all new wells pumping from the deep aquifer. Figures 11-1 through 11-4 illustrate these well fields for the two different project pumping capacities simulated in the four scenarios.

Plots of additional reservoir releases to meet flow requirements after accounting for changes in stream-aquifer interaction are presented after groundwater model results.

11.1 Scenario 1 – 100 TAF GCID, 50 TAF Butte Basin, Summer Pumping

Scenario 1 is defined by two conjunctive management projects with maximum seasonal groundwater pumping capacities of 100 TAF in GCID and 50 TAF in the Butte Basin. Environmental objectives and unmet agricultural demands are as presented in preceding sections. The pumping season spans 4 months of the irrigation season from May through August. The model first determines ability to meet environmental objectives and then uses remaining project assets to meet agricultural demands. Sensitivity to prioritization of environmental objectives and agricultural demands was evaluated and is explained in subsequent sections of this report.

The following series of plots summarize the annual operations with conjunctive management. The first series of plots summarize Sacramento River and Shasta Reservoir operations and the second series summarize Feather River and Oroville Reservoir operations. Plots are arranged in order of how operations occur each year. In winter and spring months, additional water is released from reservoirs to satisfy environmental objectives. During summer months additional water is released to meet agricultural demands. The result is that fall reservoir storage levels are lower than they would be under operations without conjunctive management projects, as shown on Figure 11-5. Reservoir storage space is typically refilled with surplus surface water during subsequent winter and spring periods. If reservoirs do not refill with surplus surface water and fall reservoir storage levels are forecasted to be low, reservoirs are refilled by pumping groundwater in conjunctive management projects and holding a similar volume of surface water in the reservoir.

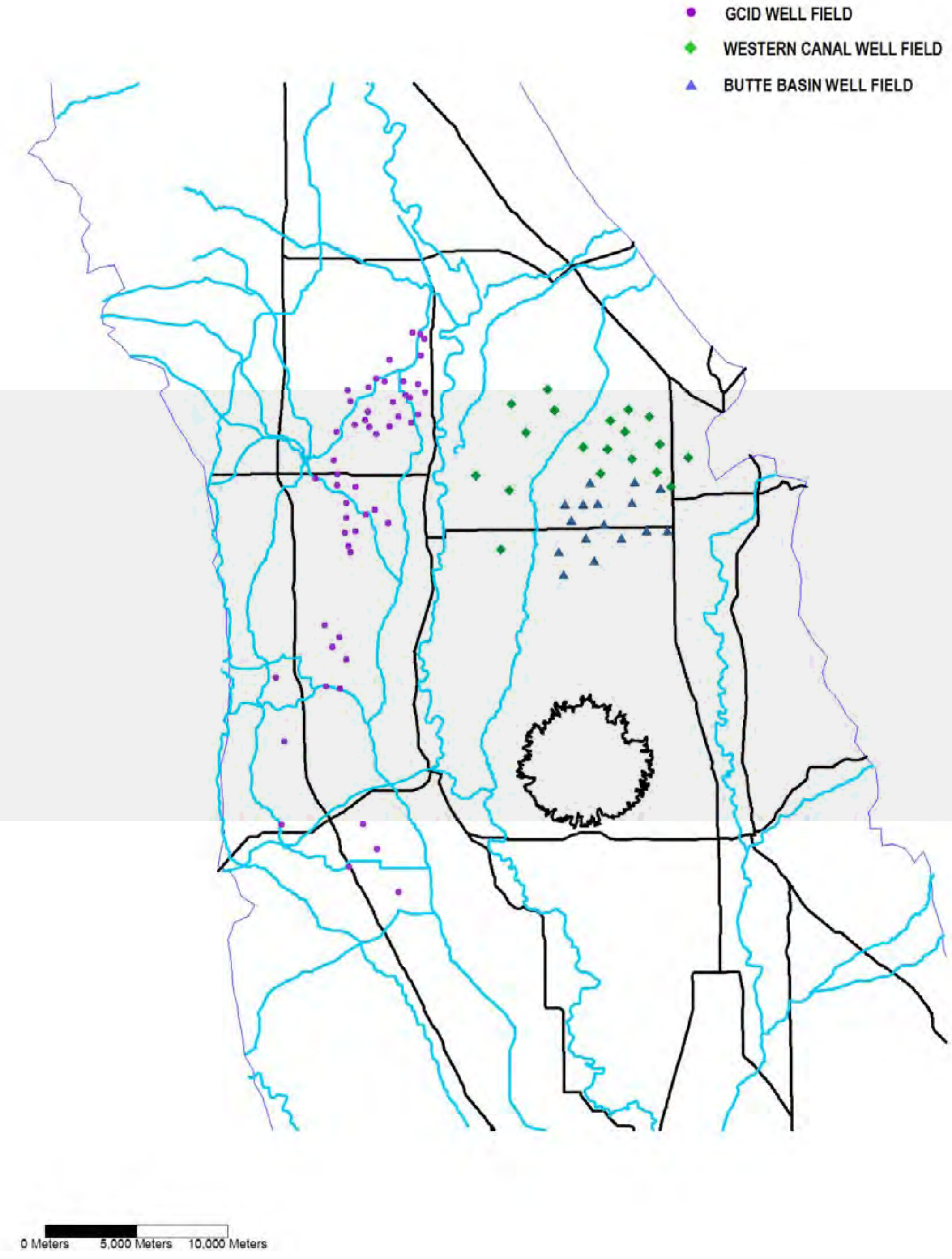


FIGURE 11-1
EXISTING WELL LOCATIONS, 150-TAF WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

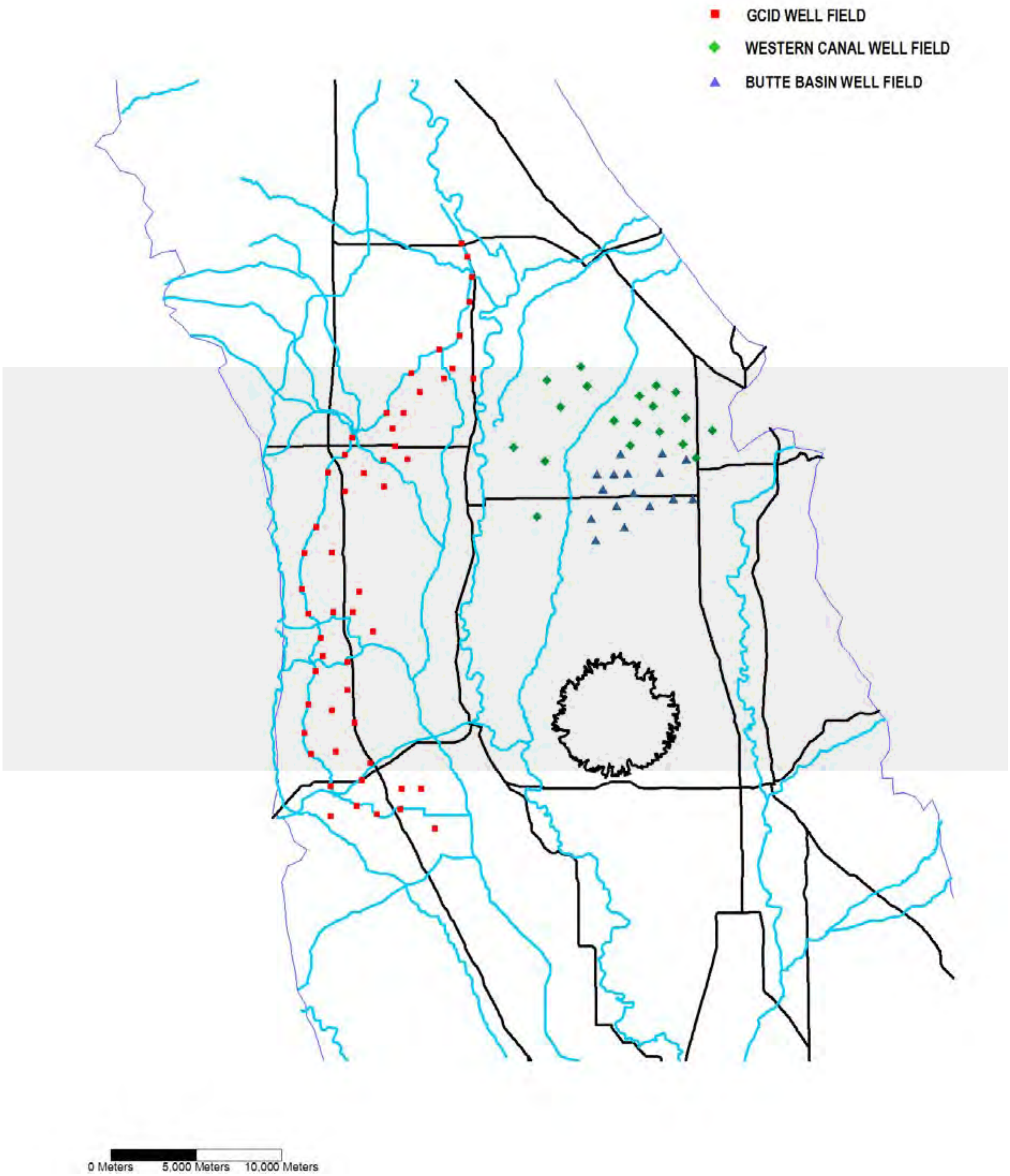


FIGURE 11-2
NEW WELL LOCATIONS, 150-TAF WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

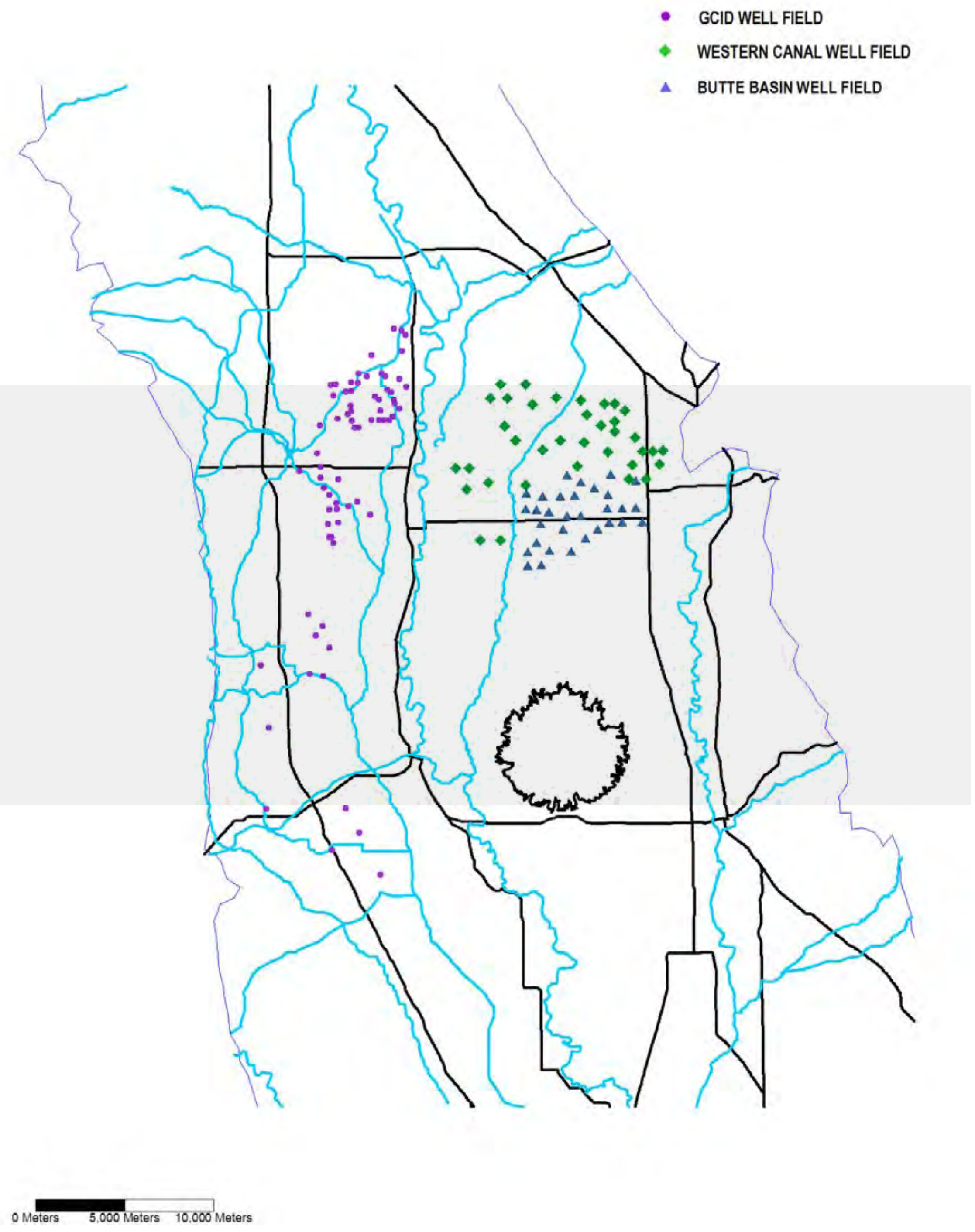


FIGURE 11-3
EXISTING WELL LOCATIONS, 300-TAF WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

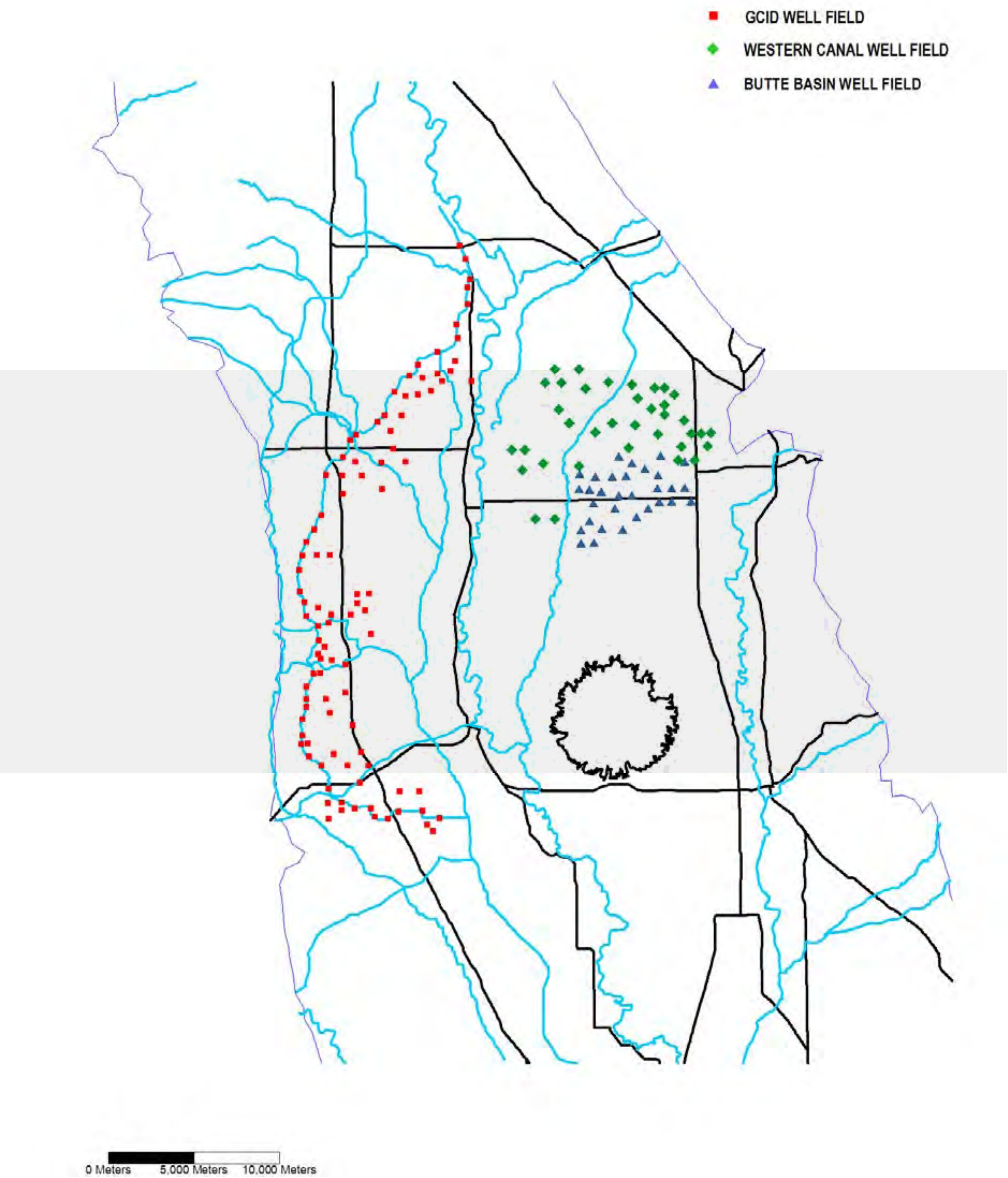


FIGURE 11-4
NEW WELL LOCATIONS, 300-TAF WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

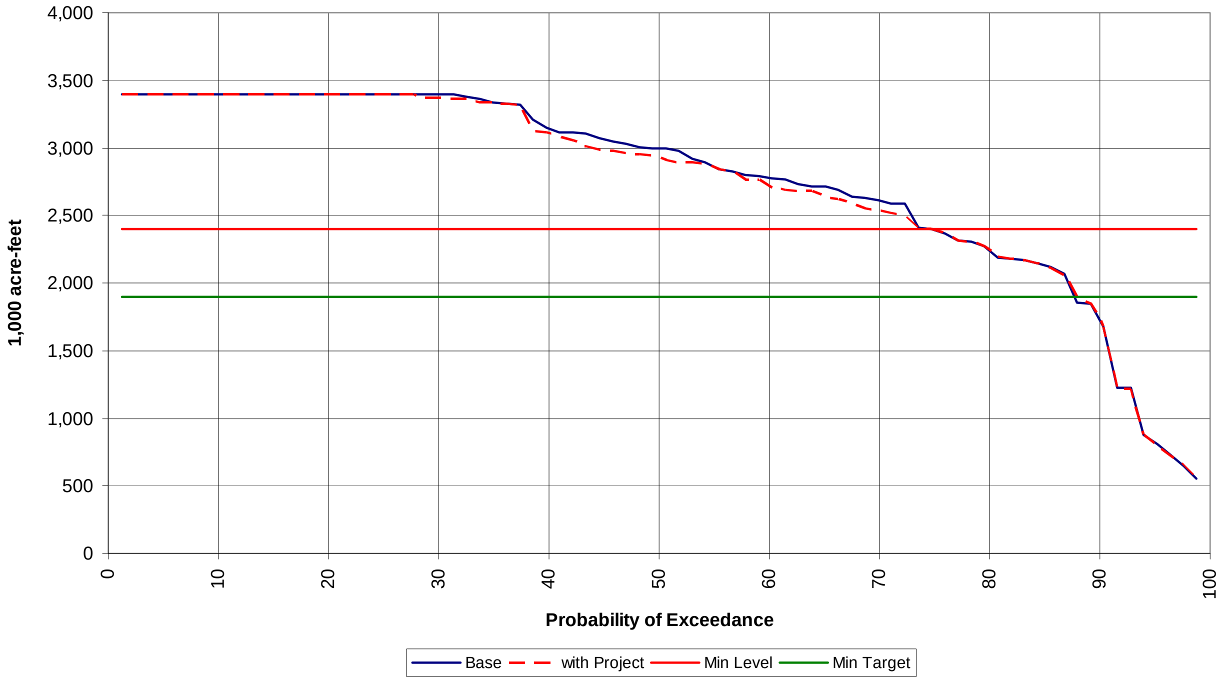


FIGURE 11-5
SHASTA RESERVOIR SEPTEMBER STORAGE EXCEEDANCE PROBABILITY WITH CONJUNCTIVE MANAGEMENT, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

11.1.1 Shasta Reservoir and Sacramento River

Figure 11-6 illustrates annual volumes of water released to satisfy various environmental objectives on the Sacramento River. Color-coded bars and the legend refer to relative priority of objectives in each year. For example, in 1928 the red bar indicates that water was released to meet objective 4, the lowest priority objective. The type of objective, either geomorphic (Geo), riparian recruitment (Rip), spring pulse (Spring), or flood plain inundation (Flood) is labeled above the corresponding bar. Geomorphic objectives are met most frequently due to lower water costs associated with the short duration objective. Average annual release for environmental objectives is 13 TAF.

Figure 11-6 shows only years when environmental objectives are met through project release. Environmental objectives are also met at times under existing system operation. This information is summarized in Table 11-1. For the flood plain inundation objective, the project includes modifications to the Freemont Weir to allow inundation with less Sacramento River flow. The existing Fremont Weir crest limits inundation of the Yolo Bypass for flows less than approximately 62,000 cfs. The project assumes it is possible to modify the weir to allow inundation with flows of approximately 35,000 cfs. Therefore this objective can be met by the project; either under base condition flows between 35,000 and 62,000 cfs (base condition flows in excess of 62,000 cfs meet the objective in the base condition) or through additional reservoir release to create flows of approximately 35,000 cfs. Results presented in Table 11-1 show the flood plain objective is met in 20 years with the project, though there are only 2 years with releases for this objective illustrated on

Figure 11-6. This indicates that the objective was met with base condition flows between 35,000 and 62,000 cfs (without additional reservoir release) in 18 years.

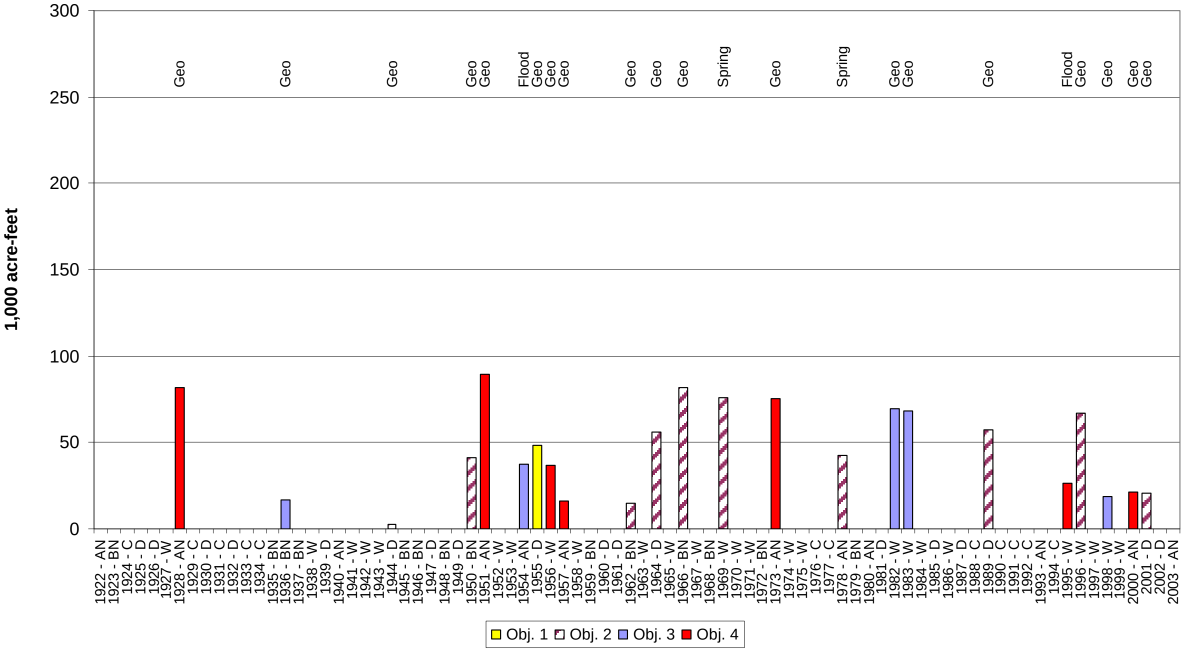


FIGURE 11-6
SACRAMENTO RIVER ENVIRONMENTAL OBJECTIVES MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

TABLE 11-1
Number of Years Sacramento River Environmental Objectives are Met, Scenario 1
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Objective	Met with Base Conditions Flows	Met with Project Flows	Total
Spring Pulse	5	2	7
Riparian Recruitment	0	0	0
Geomorphic	25	18	43
Flood Plain Inundation	21	20	41

In some years, an objective may be met with base condition flows either before or after it is met with project releases during that same year. Results presented in Table 11-1 account for these occurrences and assume the objective is met in the base condition to prevent double counting in any year. For example, Figure 11-6 shows that releases were sufficient to meet the geomorphic objective in 19 of the 82 years analyzed. However, in 1 year (1956) the objective was met both under base conditions and then simulated to be met through project release. Results presented in Table 11-1 only show this objective being met during base condition flows to prevent potential double counting.

Figure 11-7 illustrates annual releases from Shasta Reservoir to meet additional agricultural demand in the TCCA service area. Dashed lines show unmet contract supply from CalSim II results and green bars illustrate the portion of unmet contract supply satisfied with conjunctive management operations. Additional agricultural releases are made in 24 of the 82 years simulated, or approximately 29 percent of the years. The average release in those years is 46 TAF, while the average annual agricultural delivery over the 82-year simulation period is 14 TAF.

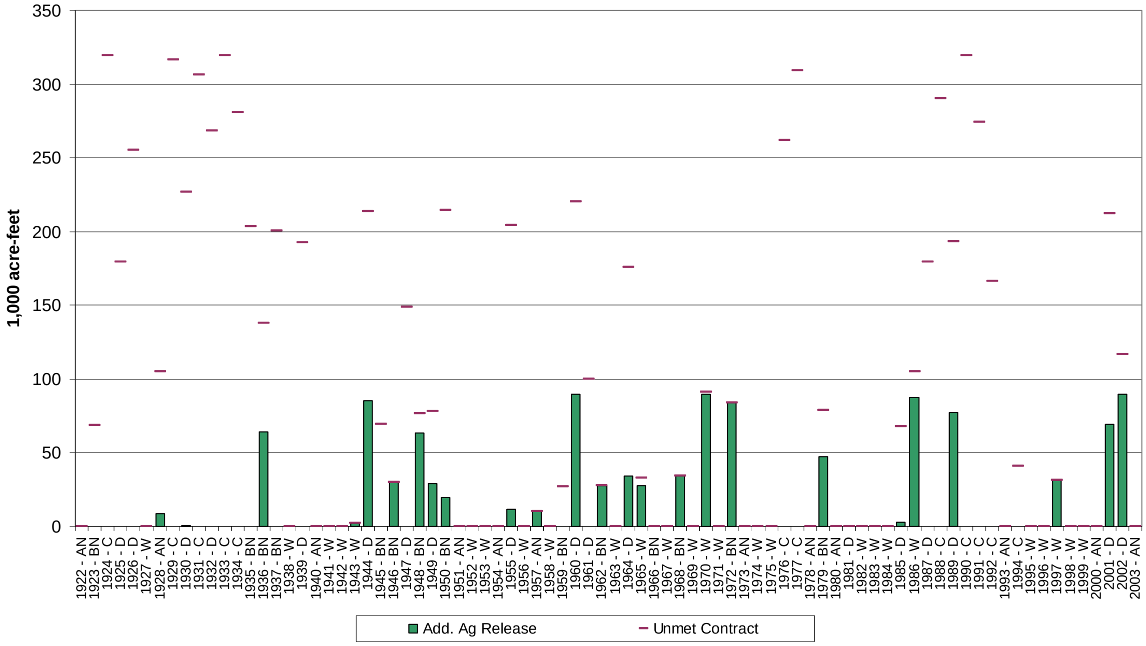


FIGURE 11-7
SACRAMENTO RIVER ADDITIONAL AG. DEMAND MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 11-7 illustrates that in many years when unmet contract supply for the TCCA is highest, there are no deliveries with conjunctive use. This is because in these years, project assets are typically low, either because fall reservoir storage is forecast to be low and no additional releases would be made or it is a Shasta Critical year and additional groundwater pumping for conjunctive management is assumed to be zero.

Additional reservoir releases for either environmental objectives or for additional agricultural delivery result in lower fall carryover storage in Lake Shasta. Figure 11-5 illustrates this with a probability of exceedance plot for end of September storage conditions. The solid blue line indicates fall storage conditions under base (without project) conditions. The red dashed line indicates conditions with conjunctive management. A solid red line at 2,400 TAF indicates the level when conjunctive management operations would not occur to limit the risk to cold water pool management in future years. Storage conditions below the solid green line at 1,900 TAF are when conjunctive management operations attempt to increase storage by pumping groundwater and holding water in Shasta above base levels.

Figure 11-5 illustrates that fall storage levels are lower in approximately 45 percent of the years and only when end of September storage is above 2,400 TAF. In wet years, when fall storage is at the flood control level of 3,400 TAF, releases in spring may refill in later months within the same year resulting in no change in fall storage conditions.

Figure 11-8 illustrates how storage deficits presented on Figure 11-5 are frequently refilled by the capture of surplus surface water. Surplus is water that would otherwise be released from the reservoir to maintain flood control storage and is not diverted downstream. This water is now stored in reservoir space created by making additional releases to meet agricultural and environmental objectives. Refill from surplus surface water occurs in 29 years with an average annual refill of 70 TAF in those years. Average annual refill with surplus surface water for the 82-year simulation is approximately 24 TAF.

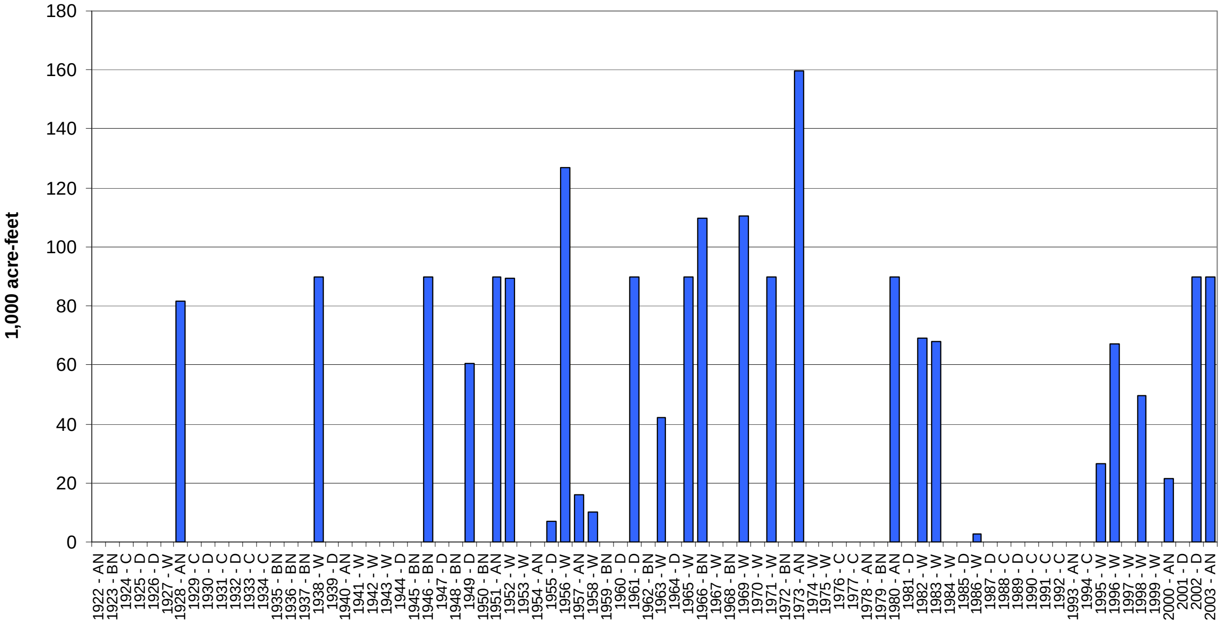


FIGURE 11-8
REFILL OF SHASTA RESERVOIR FROM SURPLUS SURFACE WATER, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

In some years, following additional reservoir releases for agricultural and environmental objectives, there is no surplus surface water, and reservoir storage levels continue to decline putting future water supplies and cold water pool management at risk. In these years groundwater pumping in the conjunctive management projects is used to recover reservoir storage levels. Figure 11-9 illustrates this annual pumping. Conjunctive management pumping occurs in 4 of the 82 years simulated, or 5 percent of years. The average annual pumping in those years is 70 TAF. The average annual pumping for the entire 82-year simulation is approximately 3 TAF with a maximum annual pumping of nearly the full 100 TAF of capacity. Pumping typically occurs in drier year types when reservoirs do not refill with surplus surface water.

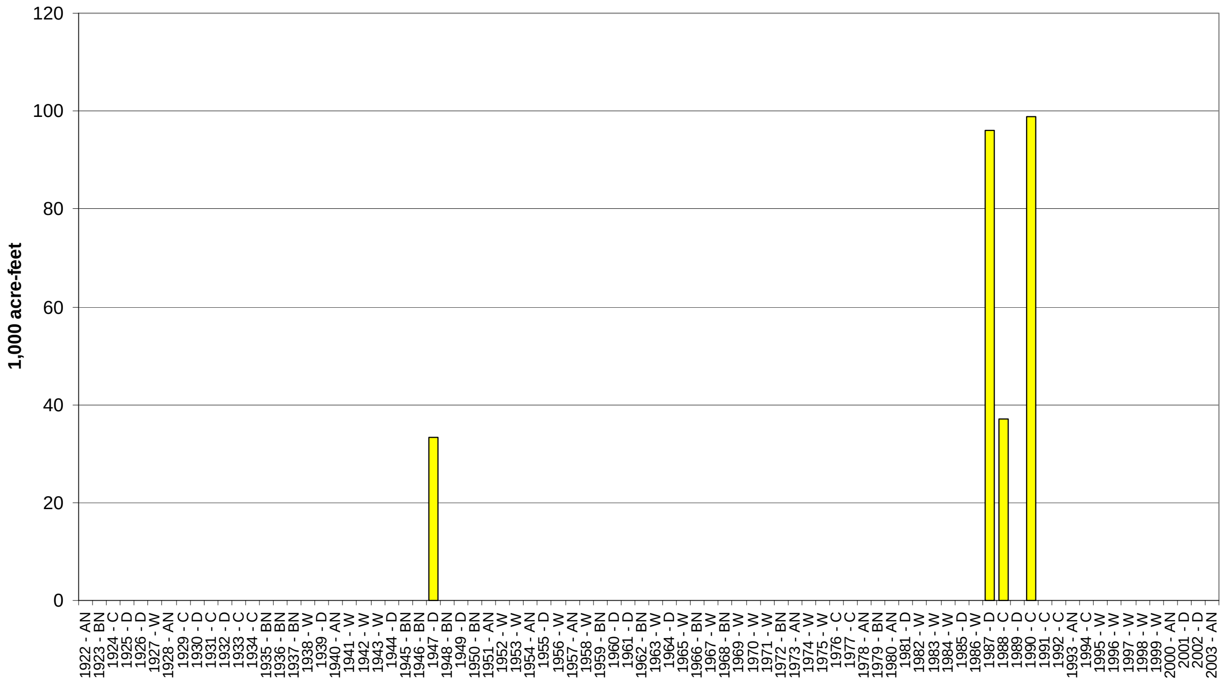


FIGURE 11-9
REFILL OF SHASTA RESERVOIR FROM CONJUNCTIVE MANAGEMENT PUMPING, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Over the 82-year simulation period, additional reservoir releases are made in 37 years, or 45 percent of the years. Reservoir refill is accomplished with surplus surface flows in 29 years and with project pumping in 4 years. The number of years with additional releases exceeds the number of years with refill because reservoir storage deficits do not have to be completely refilled before making additional releases, as long as the total reservoir storage deficit does not exceed the capacity of the project to refill the reservoir in a single year. Of the total average annual additional releases of 27 TAF (14 TAF for agriculture and 13 TAF for environmental objectives), 24 TAF is refilled from surplus surface water and 3 TAF from conjunctive management pumping.

11.1.2 Oroville Reservoir and Feather River

Figure 11-10 illustrates annual volumes of water released to meet environmental objectives on the Feather River. Hydrology and operations on the Feather River result in meeting different objectives in different years compared to the Sacramento River. Similar to the Sacramento River operations, the geomorphic objective is satisfied most frequently due to lower water cost associated with meeting the shorter duration objective. Average annual release for environmental objectives on the Feather River is 7 TAF.

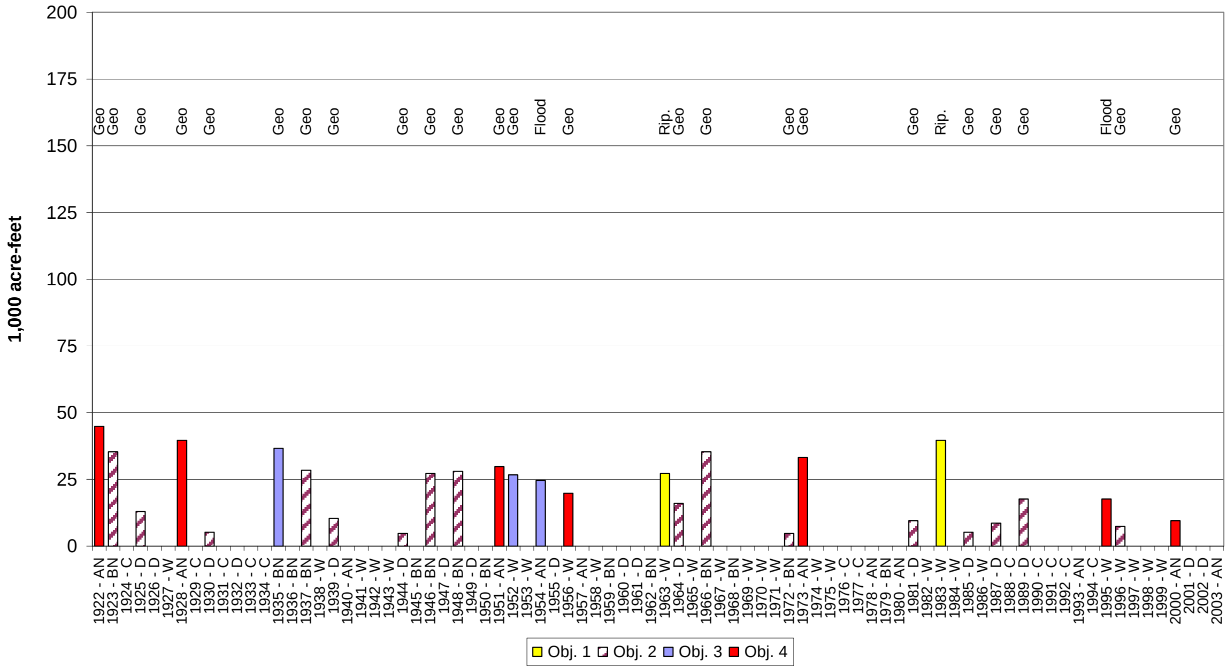


FIGURE 11-10
FEATHER RIVER ENVIRONMENTAL OBJECTIVES MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Table 11-2 provides a summary of the number of times each objective is met by reservoir release and under base operations on the Feather River. Values reported in the table for the geomorphic objective only include years when the objective is not met under base operations. Therefore this value is less than the number of releases shown on Figure 11-7. The flood plain inundation objective can be met with the project under base condition flows with the modified weir, or with a combination of project releases and the modified weir.

TABLE 11-2
Number of Years Feather River Environmental Objectives are Met, Scenario 1
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Objective	Met in Base	Met with Project	Total
Spring Pulse	3	0	3
Riparian Recruitment	1	2	3
Geomorphic	31	17	48
Flood Plain Inundation	21	20	41

Figure 11-11 illustrates additional agricultural deliveries possible with conjunctive management on the Feather River. Dashed lines relate to assumed unmet demands within the Feather River basin and correspond to the Sacramento Valley Index. Similar to operations on the Sacramento River, project assets do not allow additional releases for either environmental or agricultural objectives during drier year types when agricultural demands are higher. Additional agricultural releases are made in 30 of the 82 years simulated, or approximately 37 percent of the years. The average release in those years is 27 TAF, while the average annual agricultural delivery over the 82-year simulation period is 10 TAF.

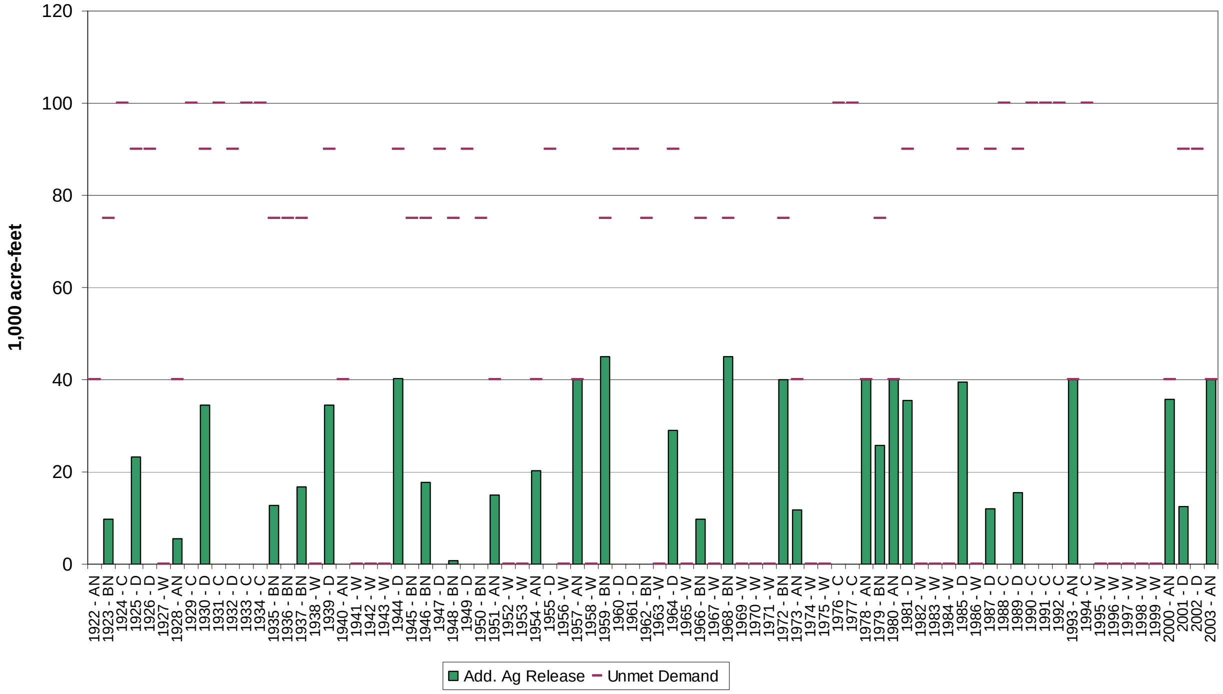


FIGURE 11-11
FEATHER RIVER ADDITIONAL AG. DEMAND MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figure 11-12 illustrates how conjunctive management operations result in slightly lower Oroville Reservoir fall storage conditions in approximately 60 percent of the years. Fall storage is not affected below the minimum level of 1,500 TAF. The solid green line at 1,200 TAF denotes target storage for cold water pool management when conjunctive management may be used to increase storage.

Figure 11-13 shows how storage space created in Oroville Reservoir through additional releases for agricultural and environmental objectives is frequently refilled with surplus surface water. Refill from surplus surface water occurs in 37 years with an average annual refill of 32 TAF in those years. The average annual refill with surplus for the 82-year simulation period is 14 TAF.

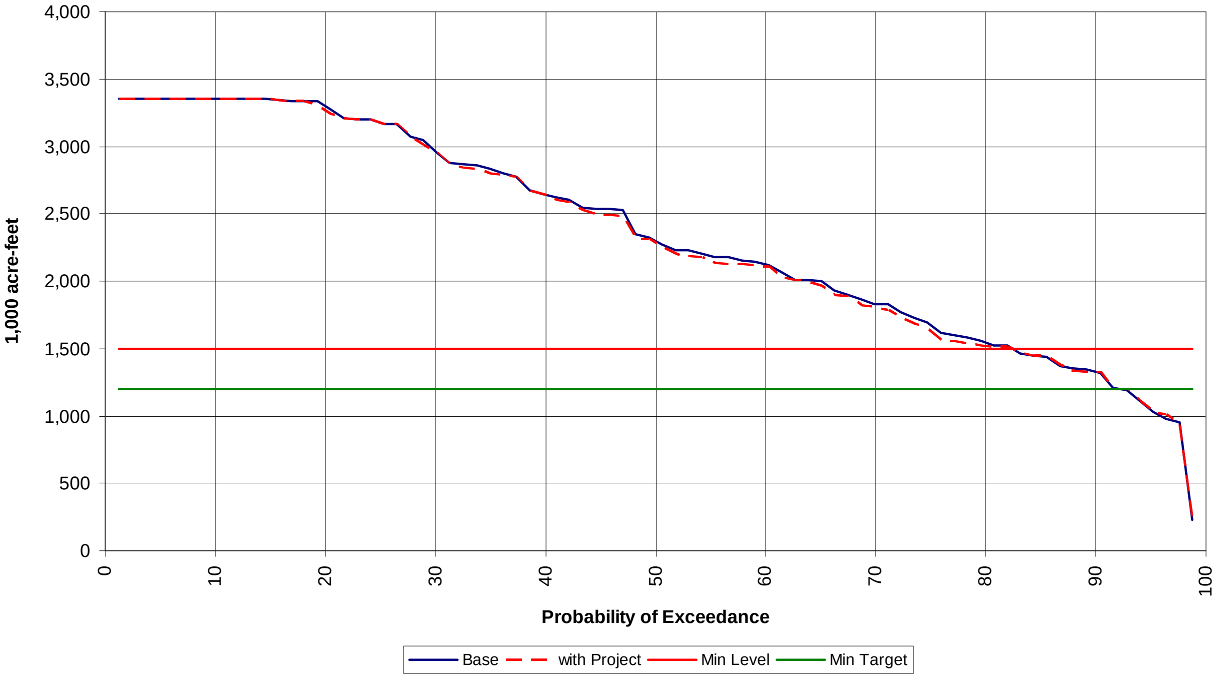


FIGURE 11-12
OROVILLE RESERVOIR SEPTEMBER STORAGE EXCEEDANCE PROBABILITY WITH CONJUNCTIVE MANAGEMENT, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

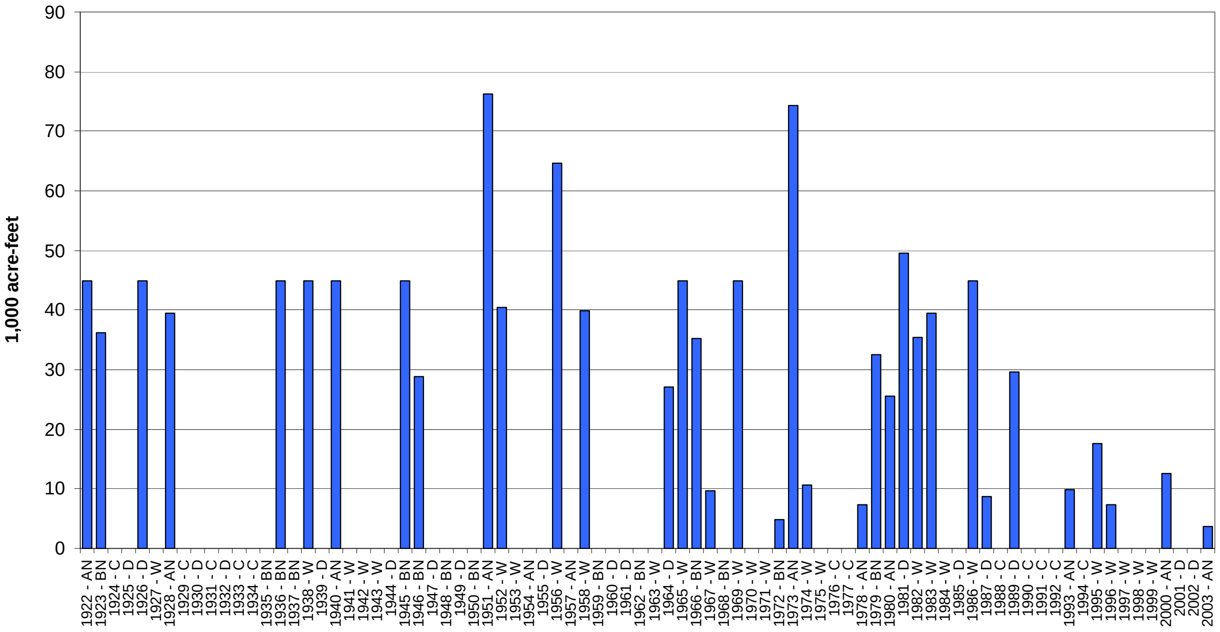


FIGURE 11-13
REFILL OF OROVILLE RESERVOIR FROM SURPLUS SURFACE WATER, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 11-14 presents annual conjunctive management pumping in the Butte Basin project. Conjunctive management pumping occurs in 6 of the 82 years simulated or 7 percent of the years. The average annual pumping in those years is 44 TAF. The average annual pumping for the entire 82-year simulation is approximately 3 TAF with a maximum annual pumping of the full 50 TAF of pumping capacity.

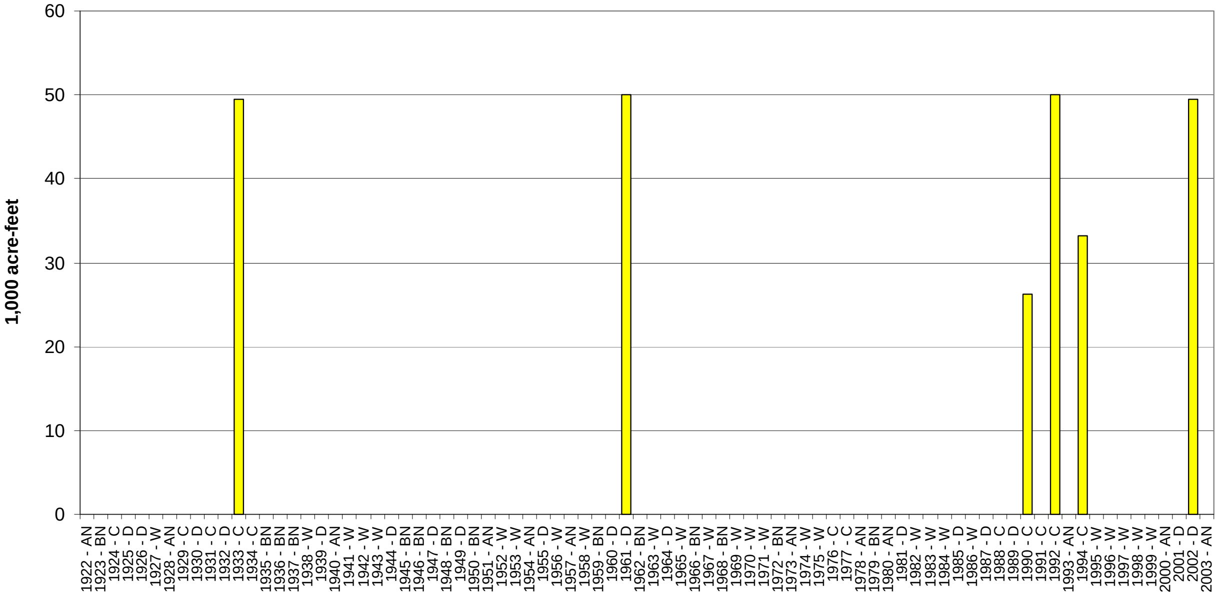


FIGURE 11-14
REFILL OF OROVILLE RESERVOIR FROM CONJUNCTIVE MANAGEMENT PUMPING, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Over the 82-year simulation period, additional reservoir releases are made in 37 years, or 45 percent of the years. Reservoir refill is accomplished with surplus surface flows in 37 years and with project pumping in 6 years. The number of years with refill exceeds the number of years with additional release because reservoir storage deficits may not completely refill in a single year, but instead refill over the course of several years. In summary, of total average annual additional releases of 17 TAF (10 TAF for agriculture and 7 TAF for environmental objectives), 14 TAF is refilled from surplus surface water and 3 TAF from conjunctive management pumping.

11.1.3 Groundwater Results

Existing Well Field

Monthly pumping for Scenario 1, illustrated on Figures 11-9 and Figure 11-14 for the GCID and Butte Basin projects, respectively, was simulated in the groundwater model for the existing well field shown on Figure 11-1. All discussions provided in this section referring to the existing well field reflect simulated drawdown in the regional aquifer. All discussions referring to the new well field reflect simulated drawdown in the deeper aquifer. Production would occur through existing wells screened in the regional aquifer at depths of 100 to

500 feet. Results of this simulation are summarized on Figures 11-15 through 11-17. Peak drawdown in groundwater levels associated with implementation of this scenario is presented on Figure 11-15. This figure depicts simulated drawdown in the pumped aquifer during August 1990. Maximum pumping rates under this alternative occur during 1990 and the drawdown distribution at the end of August represent the approximate maximum drawdown that will occur under this scenario. Figure 11-15 shows that the area of greatest drawdown occurs in the northern GCID area at a magnitude of 30 to 40 feet. Drawdown in the Butte Basin is negligible and is confined to the close vicinity of the production wells.

Simulated impacts to surface streams under Scenario 1 for an existing well field are summarized on Figures 11-16 and 11-17. These figures show that the greatest impact to surface streams will occur to the Sacramento River, between GCID and Wilkins Slough, and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-16 suggests that the peak cumulative impact to all surface water flows will be approximately 54 cfs in the summer of 1990, with a flow reduction of just more than 40 cfs forecasted to occur on the Sacramento River, and a flow reduction of approximately 13 cfs on Butte Creek. The peak impact to the Sacramento River will also occur in the late summer of 1990 while the peak impact on Butte Creek is forecasted to occur in early 1993. Peak impacts to stream flows on smaller tributary streams are less than about 6 cfs as shown on Figure 11-17.

The time of year in which impacts to rivers and streams are simulated to occur is a critical factor in assessing their significance. Typical flows in the Sacramento River at Wilkins Slough are on the order of 6,000 to 7,000 cfs in late summer and fall months with minimum flows for the historical period of 1980 through 2006 of 3,000 to 4,000 cfs. Therefore, the impacts reflected on Figure 10-16 represent a small percentage of total flow. Average summer and fall flows in the Feather River directly below Thermalito Afterbay are on the order of 2,000 to 3,000 cfs with minimum flows for the same historical period of approximately 1,000 cfs. Flows in Butte Creek near Chico average approximately 110 to 150 cfs with minimum flows of 50 cfs in some fall months. Therefore, simulated impacts to Butte Creek represent a larger percent of minimum or typical flows than impacts to the Sacramento or Feather Rivers.

Figure 11-16 illustrates stream flow reductions for the groundwater model simulation period. Reductions in the Sacramento River between GCID (Hamilton City) and Wilkins Slough show larger spikes during years with pumping in the GCID project and smaller increases during years with pumping in the Butte Basin project. Butte Creek reductions follow the opposite pattern with larger increases during years with pumping in the Butte Basin project and smaller increases in years with pumping in the GCID project. Reductions in all modeled streams show increases in years with pumping in either project. The annual cycle of increasing and decreasing reductions in all streams is due to the ephemeral nature of smaller streams. More reductions occur in winter months when smaller streams are simulated to be flowing and less reductions in summer when smaller streams are assumed to be dry.

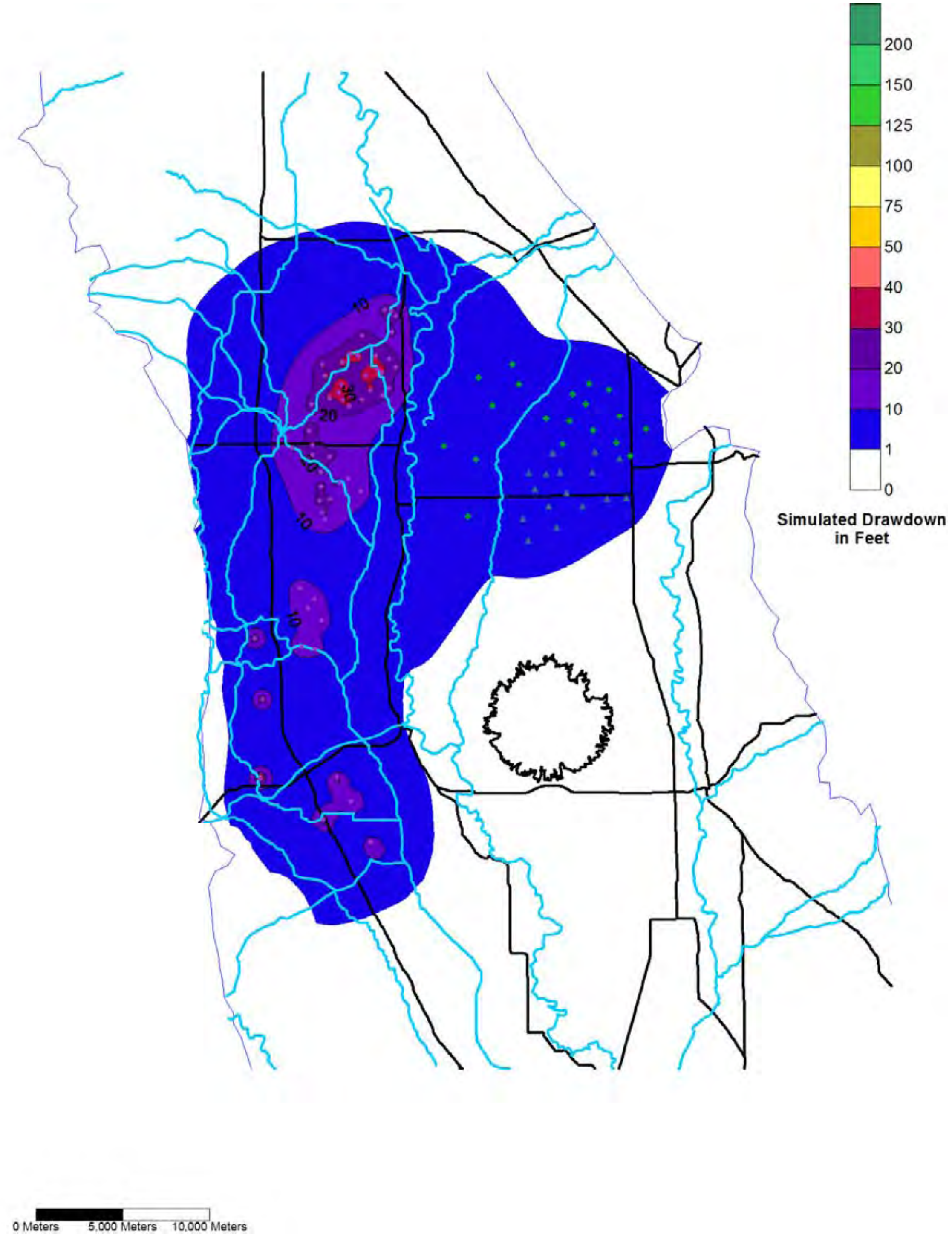


FIGURE 11-15
SIMULATED EXTENT OF DRAWDOWN IN THE REGIONAL AQUIFER IN AUG 1990, SCENARIO 1 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

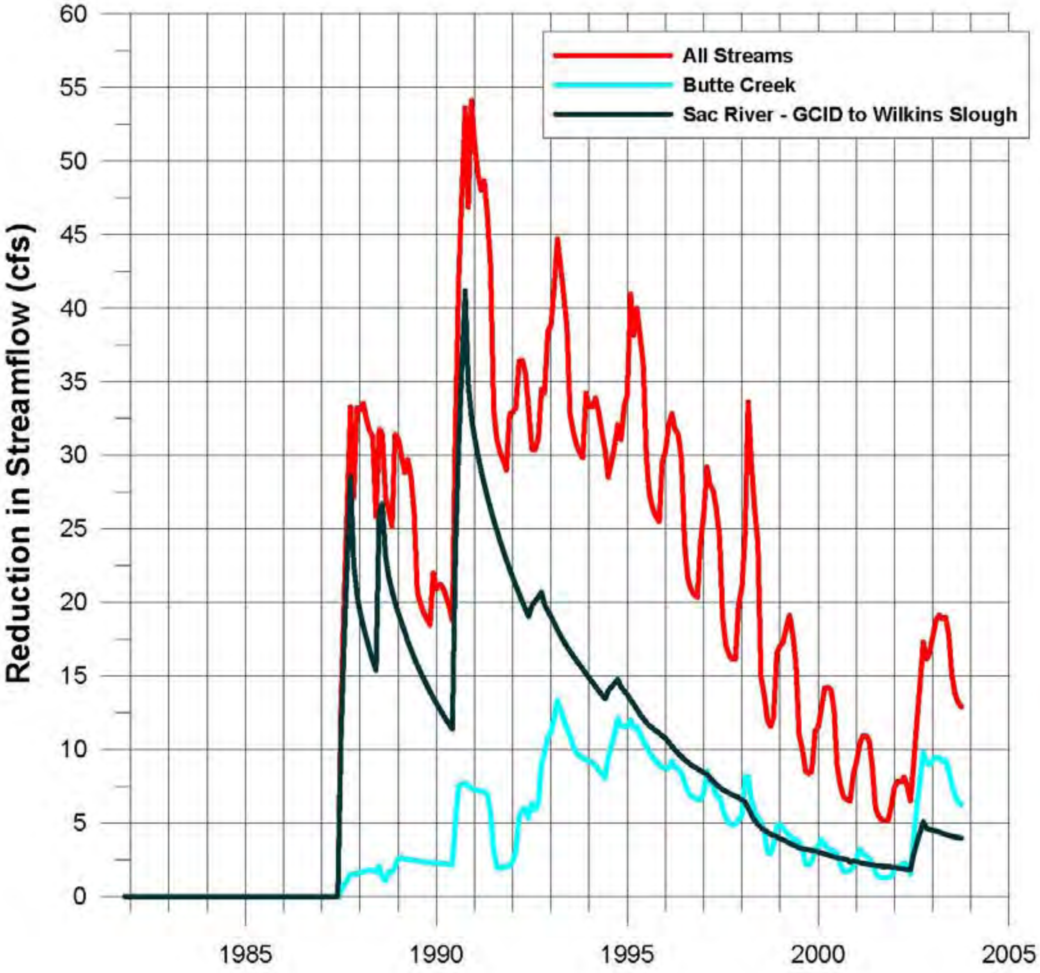


FIGURE 11-16
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 1 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

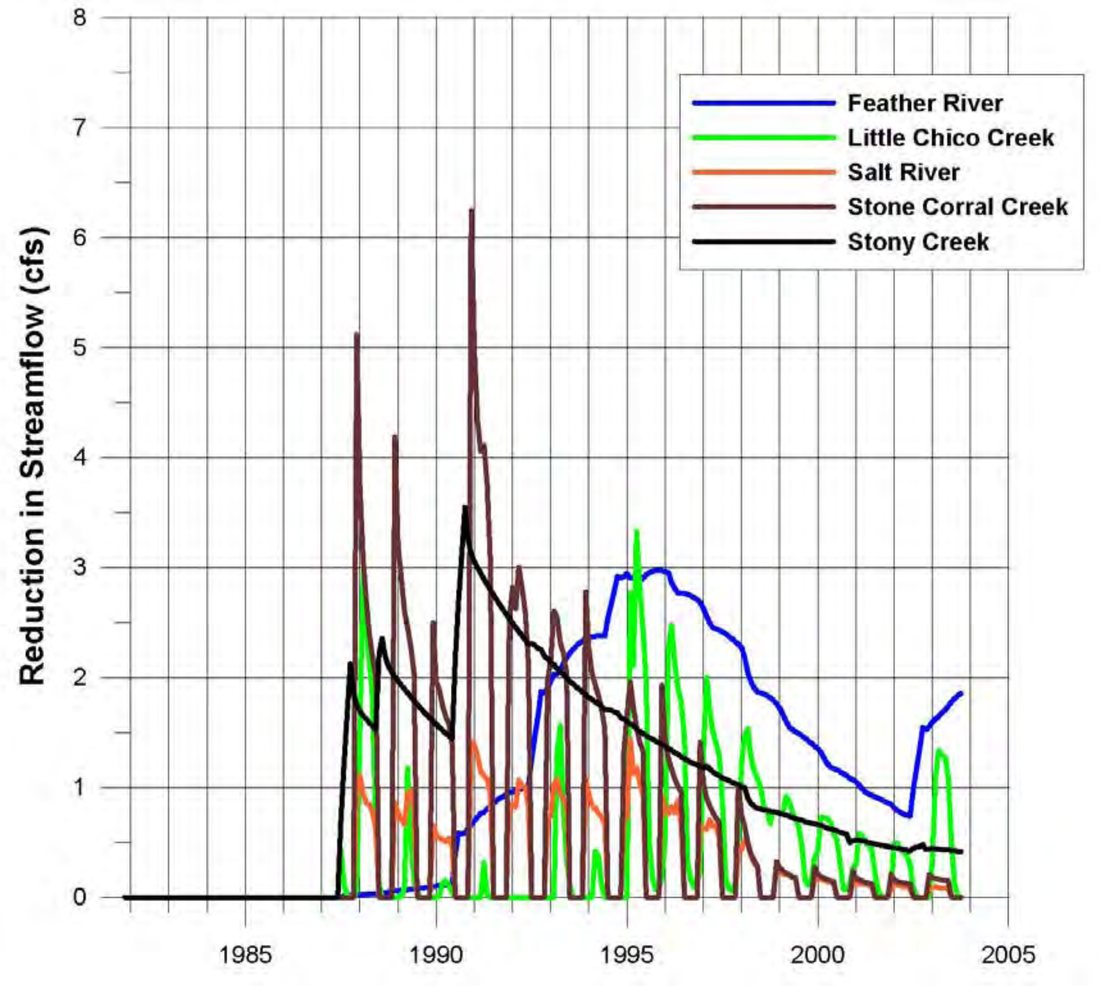


FIGURE 11-17
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 1 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Reservoir Release for Recharge

Stream reductions, due either to increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes in upstream reservoir operations. The timing of when stream reductions occur and conditions in the surface water system determine if and how the surface water system may respond. For example, if stream reductions tend to occur in winter months of years with above average precipitation there may be little or no response required by upstream reservoirs to a decrease in stream flow. Alternatively, if stream reductions occur during fall months of years with below average precipitation, upstream reservoirs may be required to make additional releases to ensure compliance with flow or water quality requirements in the surface water system.

The surface water system is sometimes referred to as being in a “balanced” or “surplus” condition. Balanced conditions occur when upstream reservoirs are releasing water to meet specific downstream requirements for flow, diversions, water quality, or to support Delta exports. Surplus conditions typically occur when upstream reservoirs are releasing water for flood control purposes or tributary inflow below reservoirs results in surplus conditions. It is possible for parts of the system to be in balanced conditions while others are in surplus conditions. For example, if Shasta Reservoir is releasing water to maintain minimum required flow at the navigation control point (a location near Wilkins Slough) the system is in balance between Shasta and Wilkins Slough and reduction in Sacramento River flow or its tributaries upstream of Wilkins Slough may require additional release from Shasta. Simultaneously there may be surplus flow in the Sacramento River below Wilkins Slough or the Delta, and reduction in stream flow downstream of Wilkins Slough may require additional release from Shasta.

Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions, upstream reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-18 and 11-19 present annual additional releases from Shasta and Oroville, respectively, for Scenario 1 pumping from an existing well field.

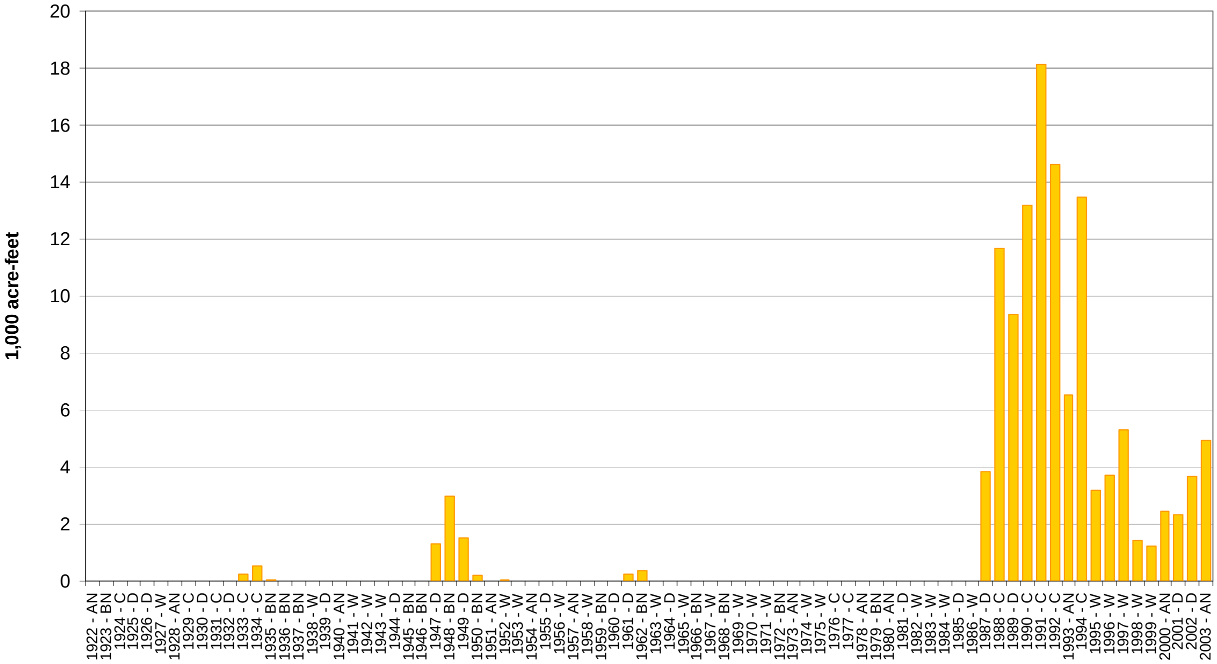


FIGURE 11-18
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 1 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

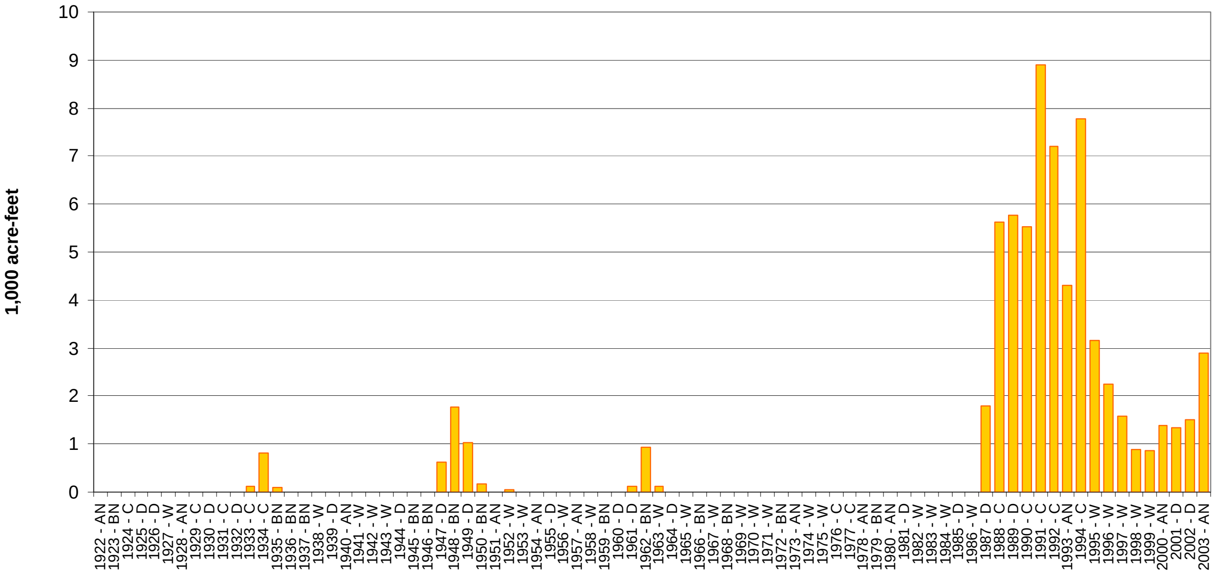


FIGURE 11-19
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 1 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figures 11-18 and 11-19 also illustrate that in multiple years with higher levels of pumping, such as the simulation from 1987 through 1994, upstream reservoirs may have to release a small volume of additional water to compensate for increases in streamflow reductions. These results reflect the precision of both the groundwater and surface water models but not necessarily the accuracy of these models. Annual releases from Oroville Reservoir of 3 TAF in any year are far beyond the accuracy of planning level models. Results are presented to demonstrate potential effects and to illustrate concepts.

New Well Field

The same monthly pumping time series for Scenario 1 was also simulated in the well field shown on Figure 11-2. Production would occur through new wells screened in the deeper aquifer units at a depth of 900 to 1100 feet. Results of this simulation are summarized on Figures 11-20 through 11-22. Peak drawdown in groundwater levels associated with implementation of this alternative is presented on Figure 11-20. This figure depicts simulated drawdown in the pumped aquifer, during August 1990. The figure shows that the area of greatest drawdown occurs in the western GCID area at a magnitude of up to 100 feet. Drawdown in Butte Basin is the range of 10 to 20 feet.

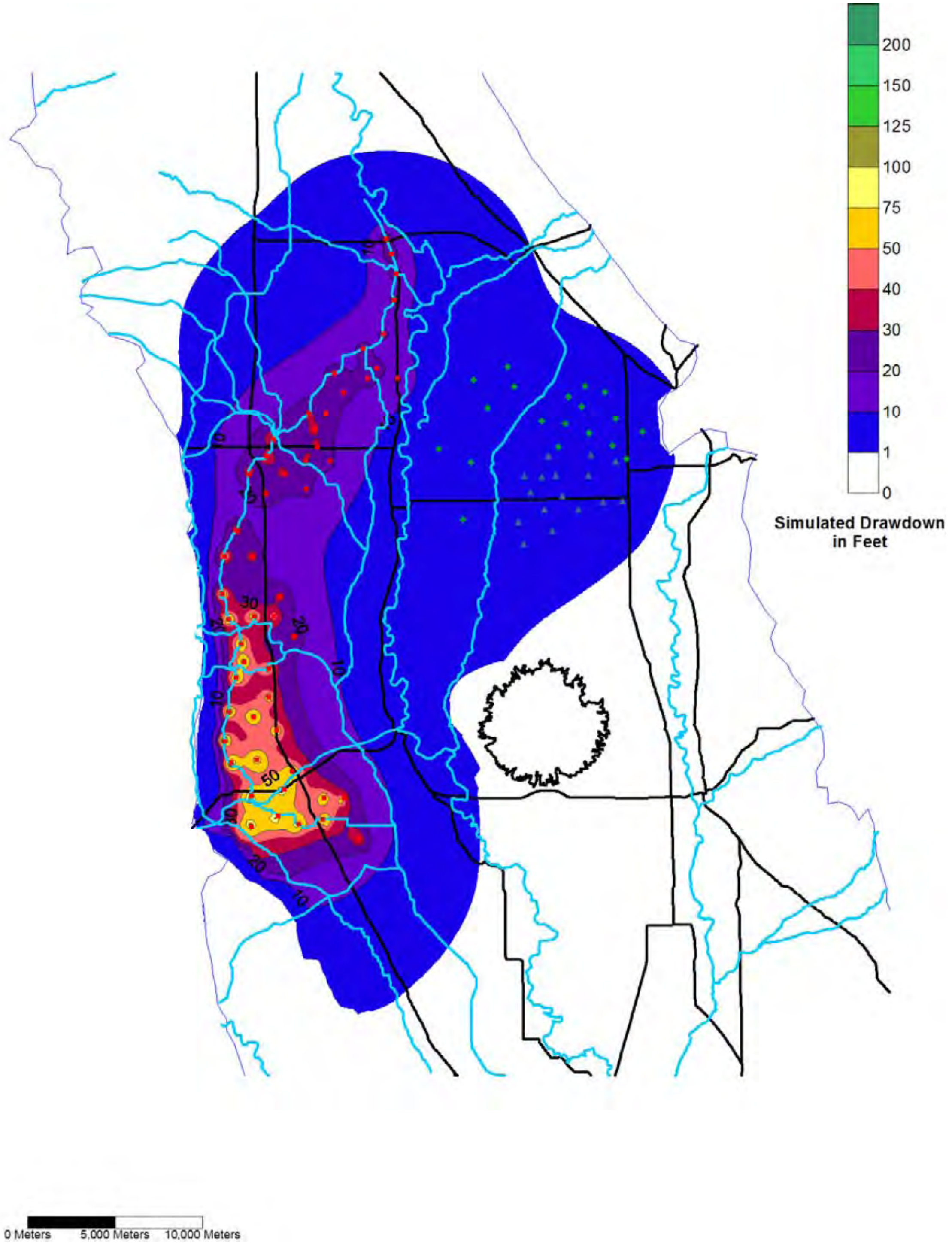


FIGURE 11-20
SIMULATED DRAWDOWN IN THE DEEP AQUIFER IN AUG 1990, SCENARIO 1 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Simulated impacts to surface streams under Scenario 1 for a new well field are summarized on Figures 11-21 and 11-22. These figures show that the greatest impact to surface streams will occur to the Sacramento River, between GCID and Wilkins Slough, and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-21 suggests that the peak cumulative impact to all surface water flows will be a reduction of about 52 cfs in the late fall of 1990, while a flow reduction of just over 36 cfs is forecast to occur on the Sacramento River while a flow reduction of approximately 12 cfs is predicted on Butte Creek. The peak impact to the Sacramento River will also occur in the late fall of 1990, while two similar peak impacts occur on Butte Creek in early 1993 and the fall of 1994. Peak impacts to stream flows on smaller tributary streams peak at less than about 9 cfs as shown on Figure 11-22.

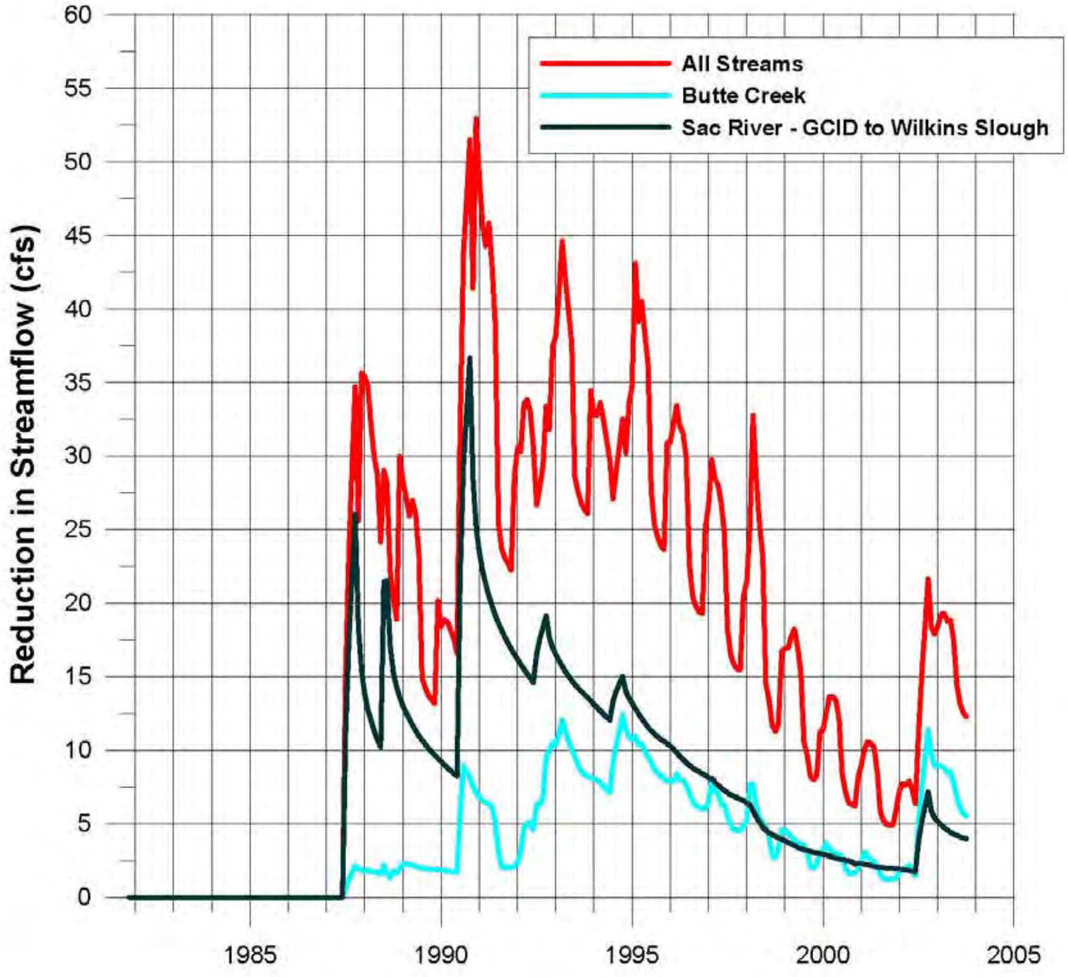


FIGURE 11-21
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 1 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

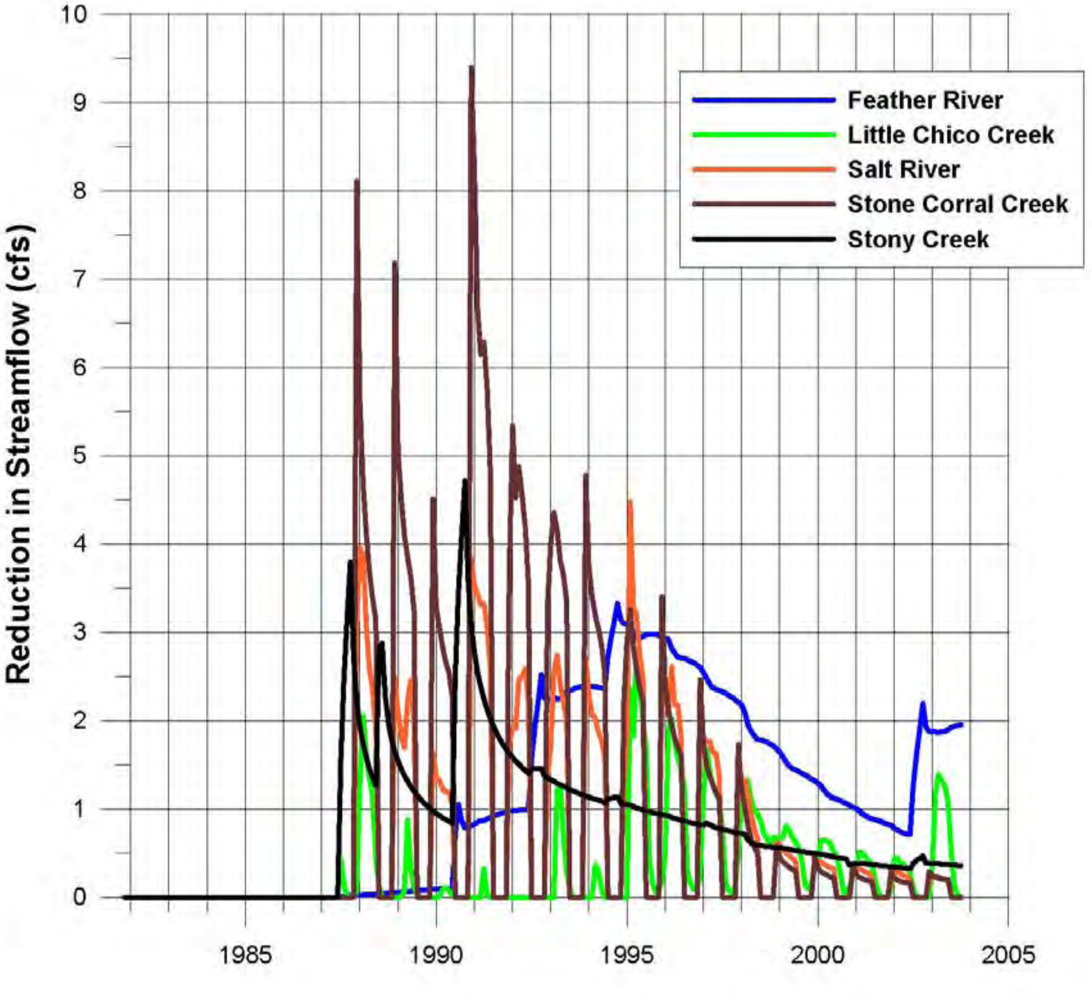


FIGURE 11-22
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 1 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Reservoir Release for Recharge

Streamflow reductions, due either to increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes in upstream reservoir operations. Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions, upstream reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-23 and 11-24 present annual additional releases from Shasta and Oroville, respectively, for Scenario 1 pumping from a new well field.

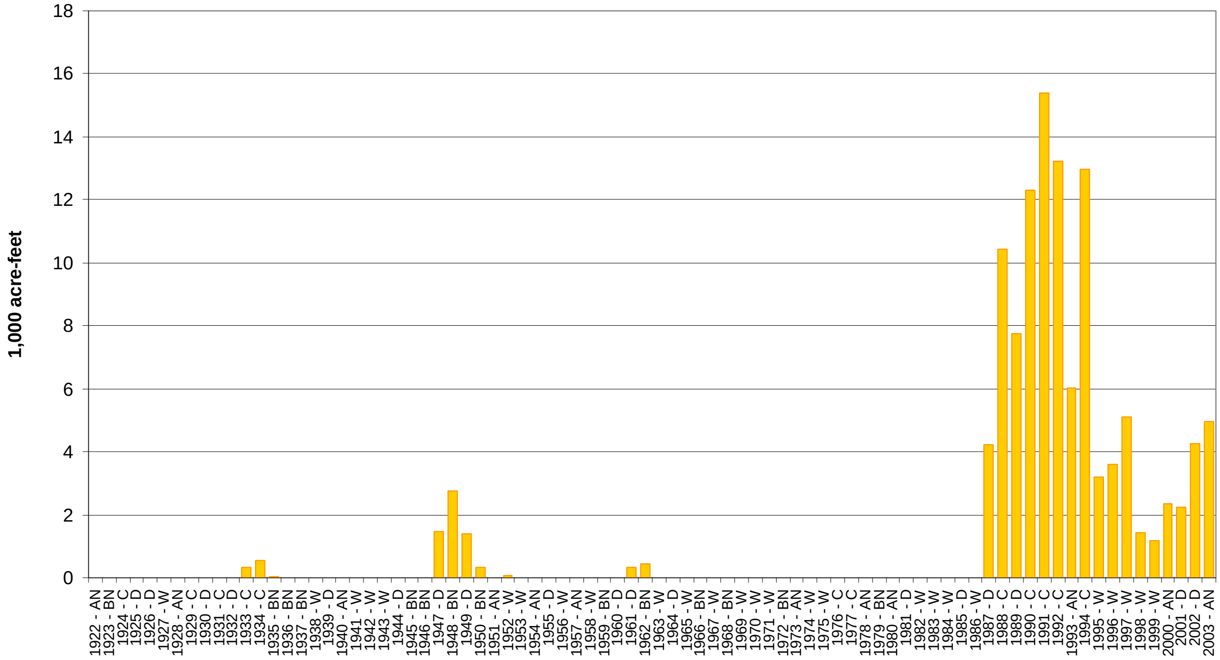


FIGURE 11-23
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 1 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

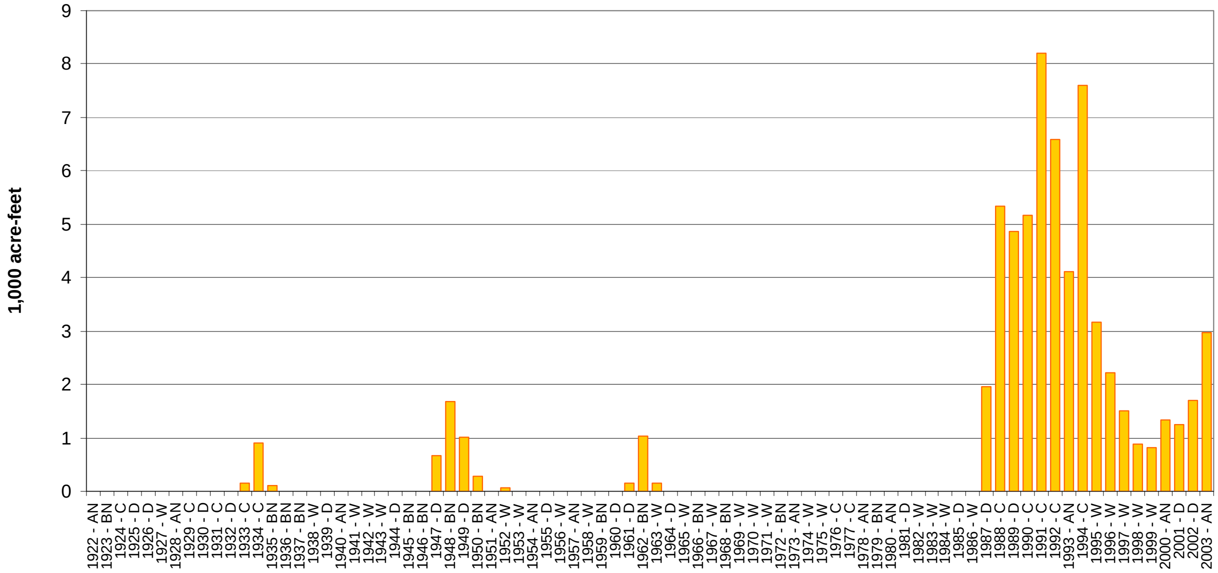


FIGURE 11-24
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 1 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figures 11-23 and 11-24 illustrate peak annual reservoir releases to compensate for stream reductions may be slightly less for a new well field than for the existing well field, but annual releases are similar for either well field.

11.2 Scenario 2 – 200 TAF GCID, 100 TAF Butte Basin, Summer Pumping

Scenario 2 is defined by two conjunctive management projects with maximum seasonal pumping capacities of 200 TAF in GCID and 100 TAF in the Butte Basin. This scenario is the same as Scenario 1 but with twice the pumping capacity at each project.

11.2.1 Shasta Reservoir and Sacramento River

Figure 11-25 illustrates annual volumes of water released to satisfy various environmental objectives on the Sacramento River. The geomorphic objective is met most frequently due to lower water cost associated with the short duration, but the larger pumping capacity increases project assets and allows other objectives to be met more frequently than in Scenario 1. Additionally, in some years more than one objective may be met as indicated by stacked bars. Average annual release for environmental objectives under Scenario 2 is 45 TAF.

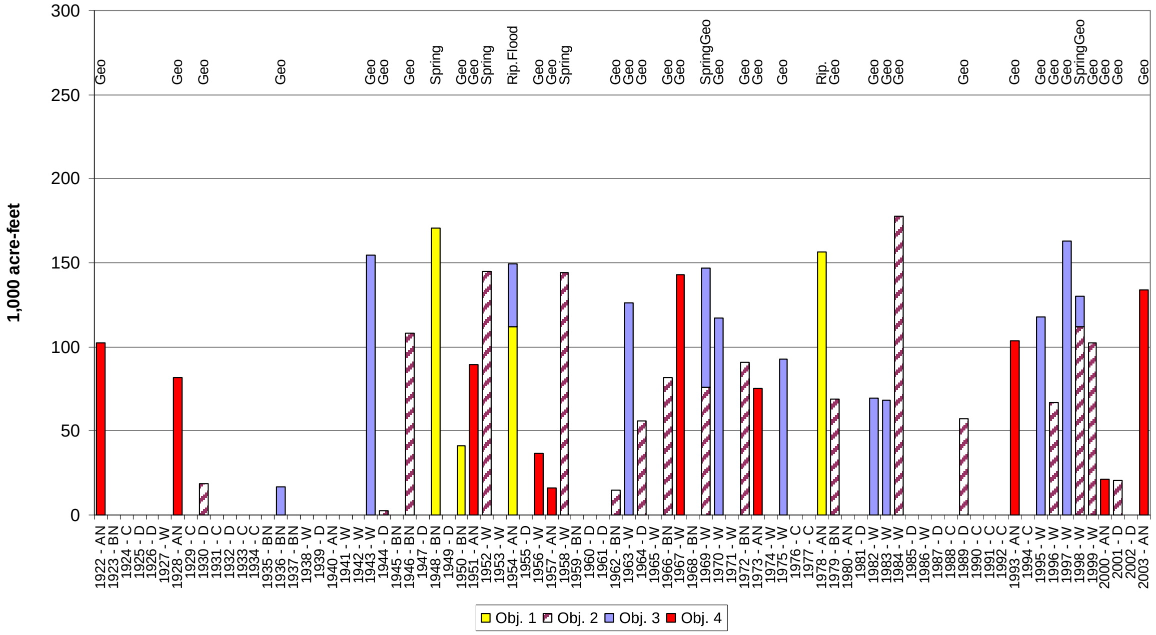


FIGURE 11-25
SACRAMENTO RIVER ENVIRONMENTAL OBJECTIVES MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 11-25 shows only years when environmental objectives are met through project release. Environmental objectives may also be met under the base operations of the system.

Table 11-3 provides a summary of the number of times each objective is met by reservoir release and under base operations on the Feather River. Values reported in the table for the geomorphic objective only include those years when the objective is not met under base operations. Therefore this value is less than the number of releases shown on Figure 11-25. The flood plain inundation objective can be met with the project under base condition flows with the modified weir, or with a combination of project releases and the modified weir.

TABLE 11-3
Number of Years Sacramento River Environmental Objectives are Met, Scenario 2
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Objective	Met in Base	Met with Project	Total
Spring Pulse	5	5	10
Riparian Recruitment	0	2	2
Geomorphic	25	30	55
Flood Plain Inundation	21	20	41

Figure 11-26 illustrates annual release from Shasta to meet additional agricultural demand in the TCCA service area. Additional agricultural releases are made in 24 of the 82 years simulated, or approximately 29 percent of the years. The average release in those years is 75 TAF, while the average annual agricultural delivery over the 82-year simulation period is 22 TAF. Additional agricultural deliveries are made in many of the same years as in Scenario 1, but at higher volumes.

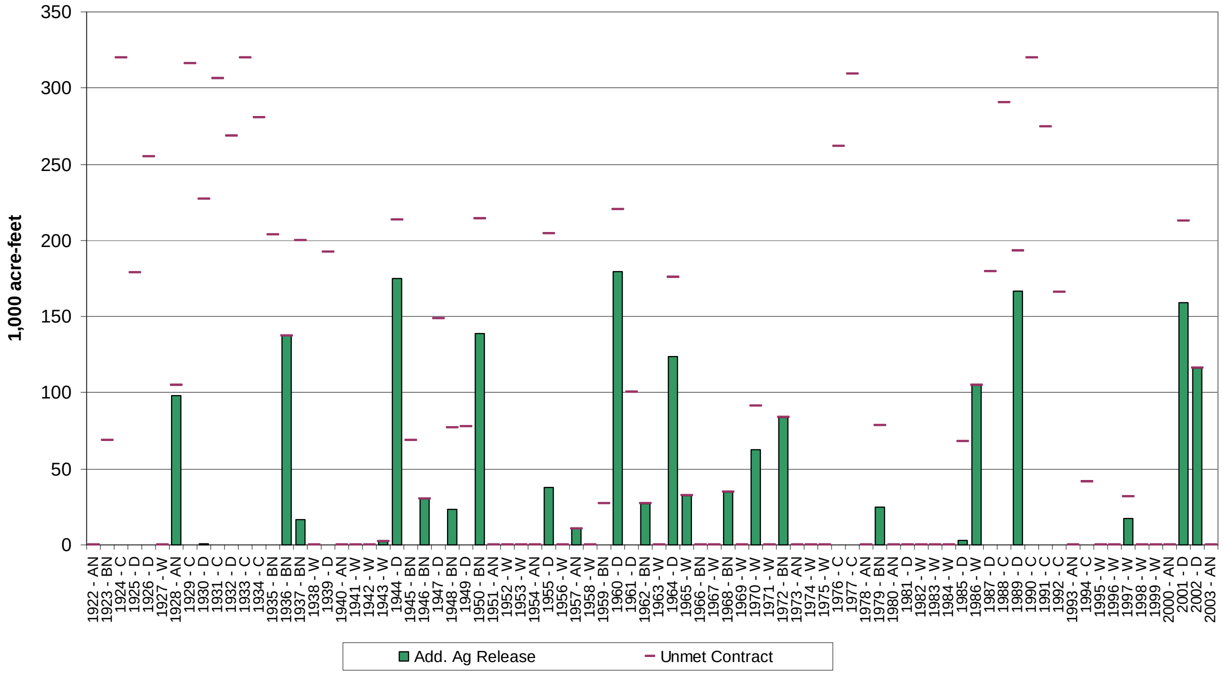


FIGURE 11-26
SACRAMENTO RIVER ADDITIONAL AG. DEMAND MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Additional reservoir releases for either environmental objectives or for additional agricultural delivery result in lower fall carryover storage in Lake Shasta. Figure 11-27 illustrates that fall storage levels are lower in approximately 45 percent of the years and only when end of September storage is more than 2,400 TAF. During these years fall storages are lower compared to Scenario 1 because larger pumping capacity allows for more aggressive operation of the reservoir. Additionally, a small increase in fall storage below the 1,900 TAF target may also be possible.

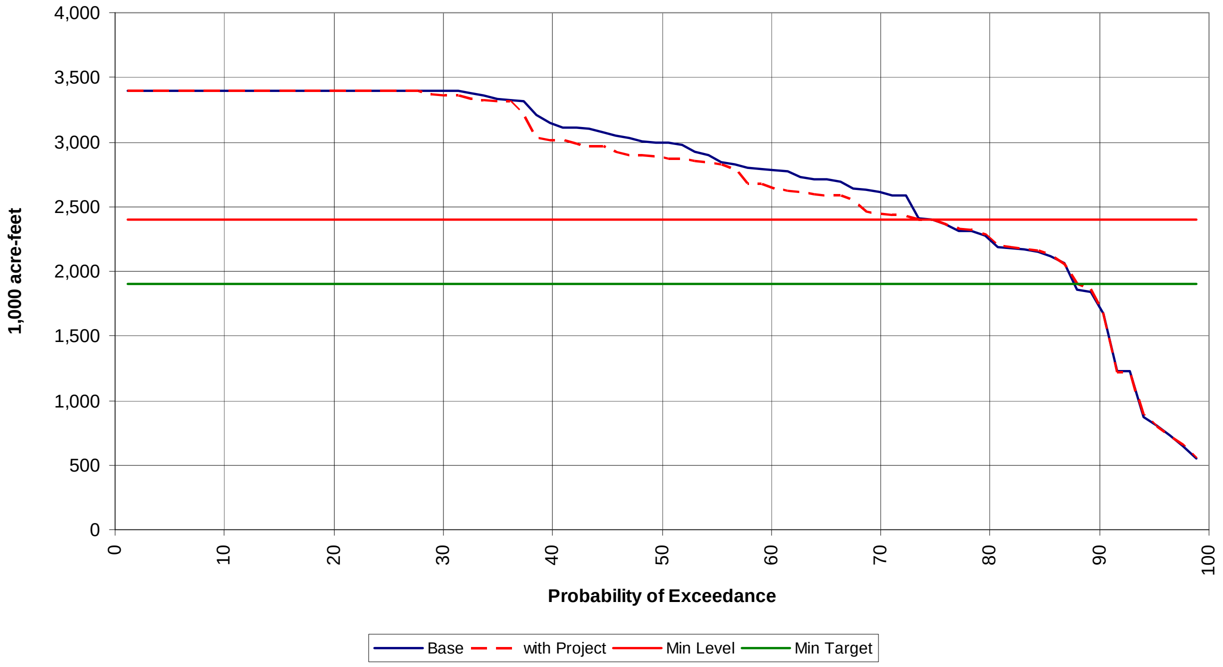


FIGURE 11-27
SHASTA RESERVOIR SEPTEMBER STORAGE EXCEEDANCE PROBABILITY WITH CONJUNCTIVE MANAGEMENT, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 11-28 illustrates how storage deficits presented on Figure 11-27 are frequently refilled by capture of surplus surface water. Refill with surplus surface water occurs in 35 years with an average annual refill of 139 TAF in those years. Average annual refill with surplus surface water for the 82-year simulation is approximately 58 TAF.

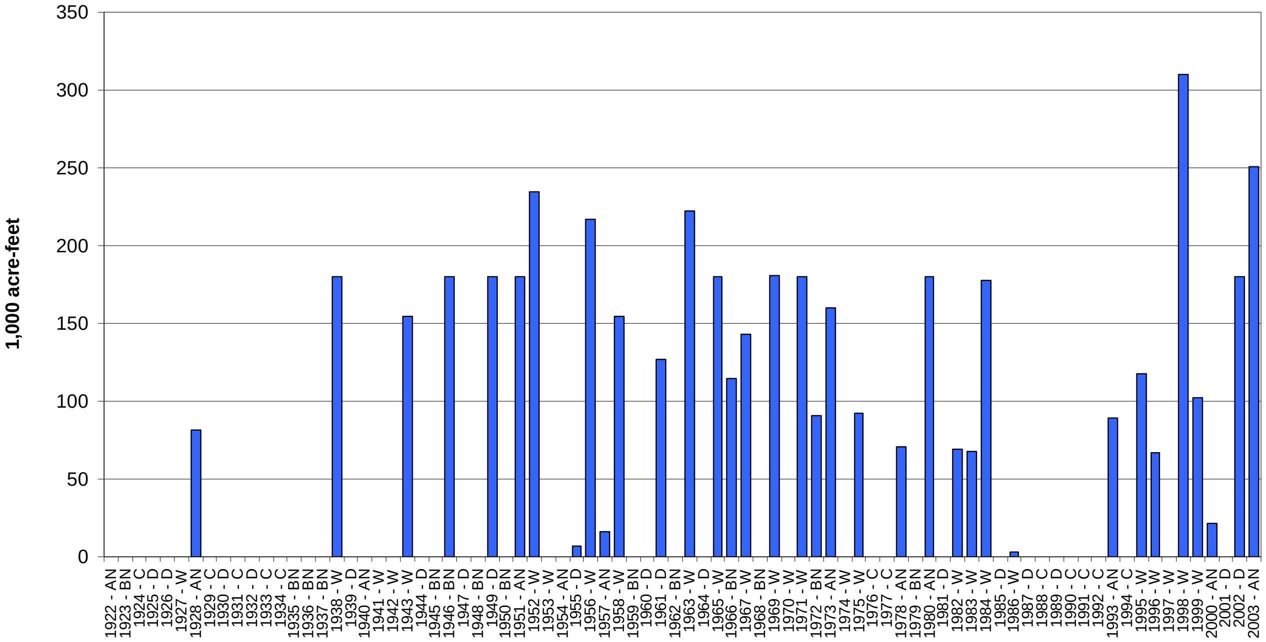


FIGURE 11-28
REFILL OF SHASTA RESERVOIR FROM SURPLUS SURFACE WATER, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figure 11-29 illustrates annual conjunctive management groundwater pumping for Scenario 2. Conjunctive management pumping occurs in 6 of the 82 years simulated, or 7 percent of years. The average annual pumping in those years is 123 TAF. The average annual pumping for the entire 82-year simulation is approximately 9 TAF with a maximum annual pumping of nearly the full 200 TAF of capacity. Pumping typically occurs in drier year types when reservoirs do not refill with surplus surface water.

Over the 82-year simulation period, additional reservoir releases are made in 48 years, or 59 percent of the years. Reservoir refill is accomplished with surplus surface flows in 35 years and with project pumping in 6 years. The number of years with releases exceeds the number of years with refill because reservoir storage deficits do not have to be completely refilled before making additional releases, as long as the total reservoir storage deficit does not exceed the capacity of the project to refill the reservoir in a single year. In summary, of total average annual additional releases of 67 TAF (22 TAF for agriculture and 45 TAF for environmental objectives), 58 TAF is refilled from surplus surface water and 9 TAF from conjunctive management pumping.

11.2.2 Oroville Reservoir and Feather River

Figure 11-30 illustrates annual volumes of water released to meet environmental objectives on the Feather River. Similar to the Sacramento River operations, the geomorphic objective is satisfied most frequently, but increased groundwater pumping capacity allows for more aggressive reservoir operations allowing other objectives to also be satisfied. Average annual release for environmental objectives on the Feather River is 23 TAF.

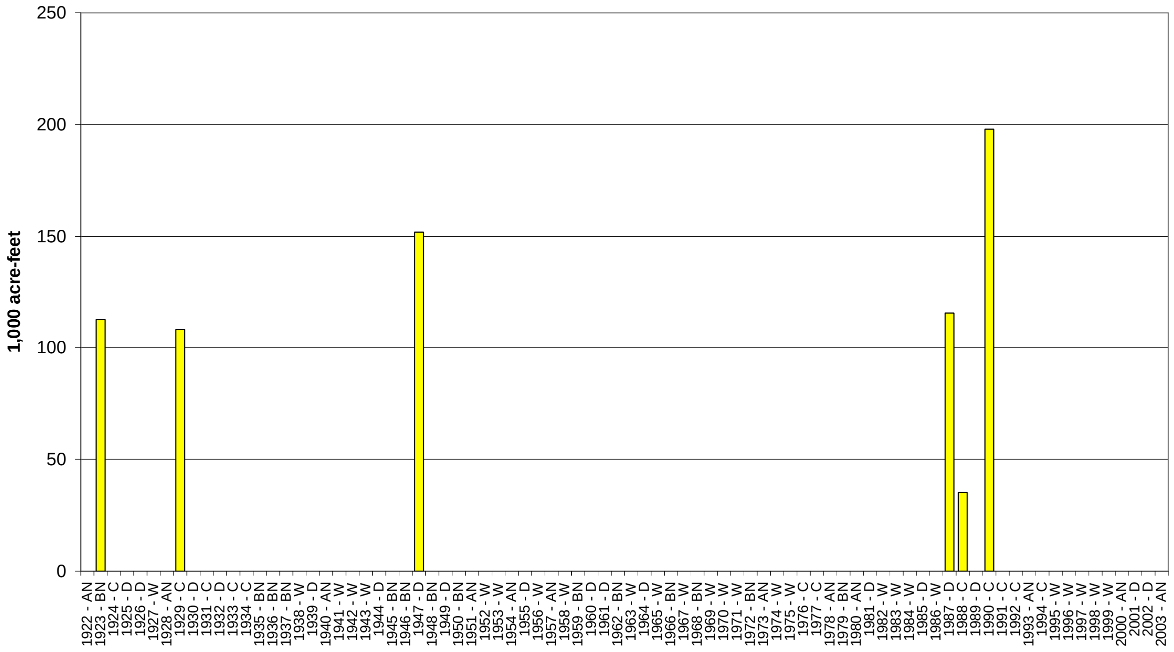


FIGURE 11-29
REFILL OF SHASTA RESERVOIR FROM CONJUNCTIVE MANAGEMENT PUMPING, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

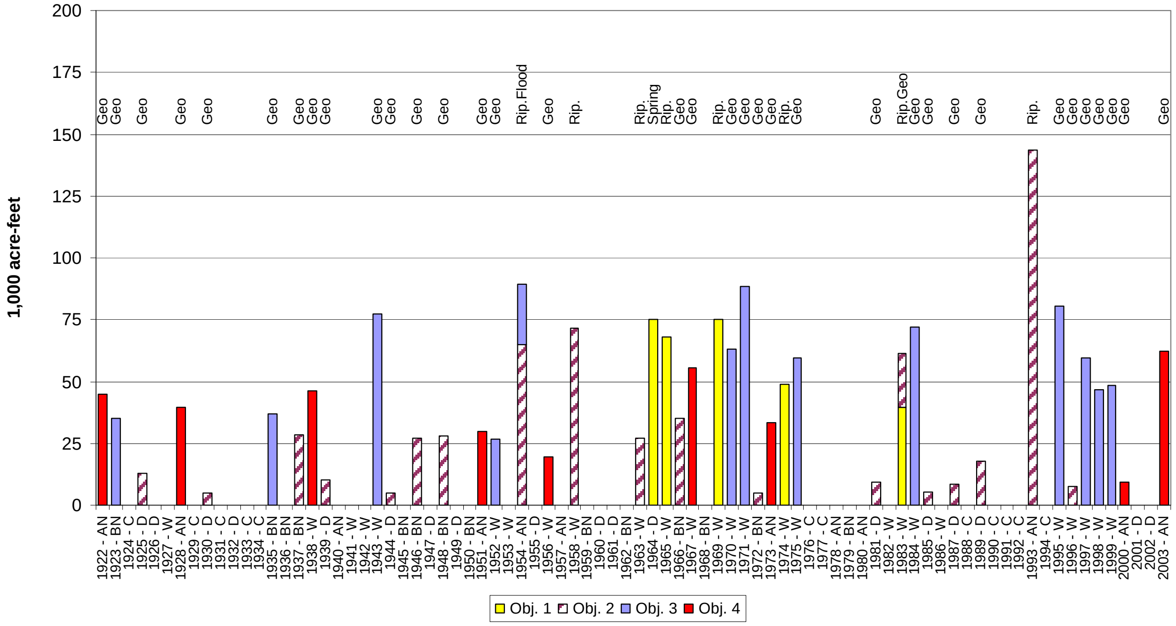


FIGURE 11-30
FEATHER RIVER ENVIRONMENTAL OBJECTIVES MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Table 11-4 provides a summary of the number of times each objective is met by reservoir release and under base operations on the Feather River. Values reported in the table for the geomorphic objective only include those years when the objective is not met under base operations. Therefore this value is less than the number of releases shown on Figure 11-30. The flood plain inundation objective can be met with the project under base condition flows with the modified weir, or with a combination of project releases and the modified weir.

TABLE 11-4
Number of Years Feather River Environmental Objectives are Met, Scenario 2
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

Objective	Met in Base	Met with Project	Total
Spring Pulse	3	1	4
Riparian Recruitment	1	8	9
Geomorphic	31	25	56
Flood Plain Inundation	21	20	41

Figure 11-31 illustrates additional agricultural deliveries under Scenario 2. Additional agricultural releases are made in 30 of the 82 years simulated, or approximately 37 percent of the years. The average annual release in those years is 52 TAF, while the average annual agricultural delivery over the 82-year simulation period is 20 TAF.

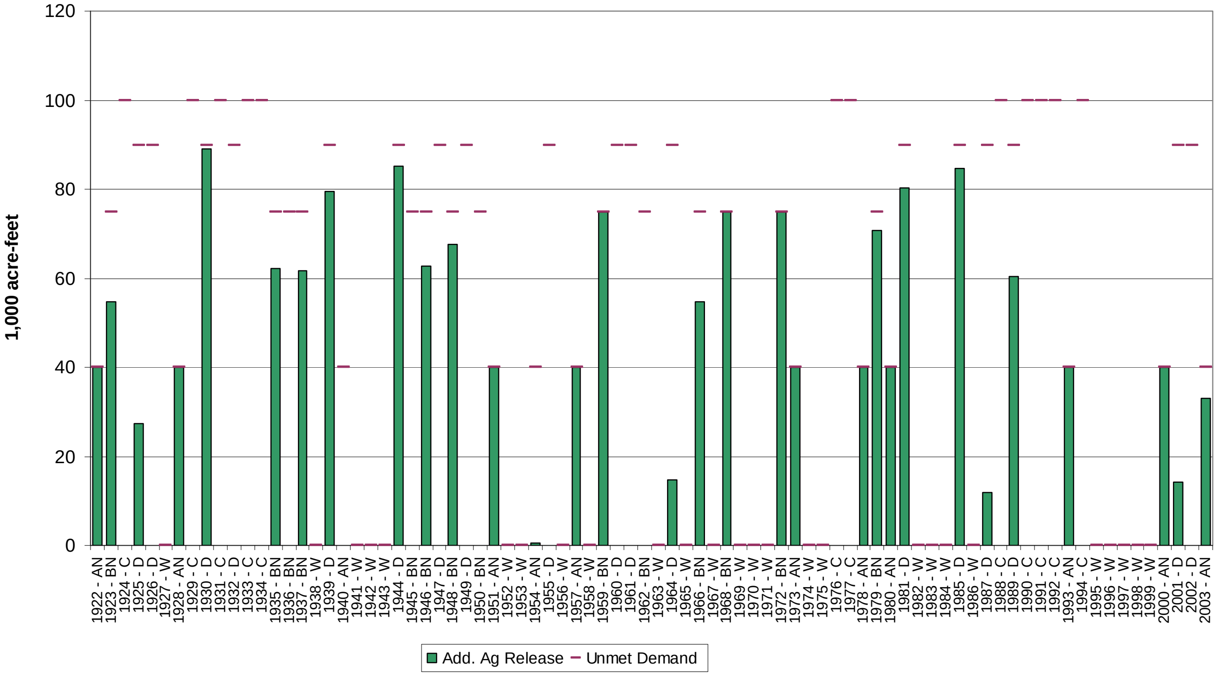


FIGURE 11-31
FEATHER RIVER ADDITIONAL AG. DEMAND MET WITH CONJUNCTIVE MANAGEMENT, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figure 11-32 illustrates how conjunctive management operations result in lower Oroville fall storage conditions in approximately 60 percent of the years. Fall storage may be increased in a few years when it is below the minimum target level of 1,200 TAF.

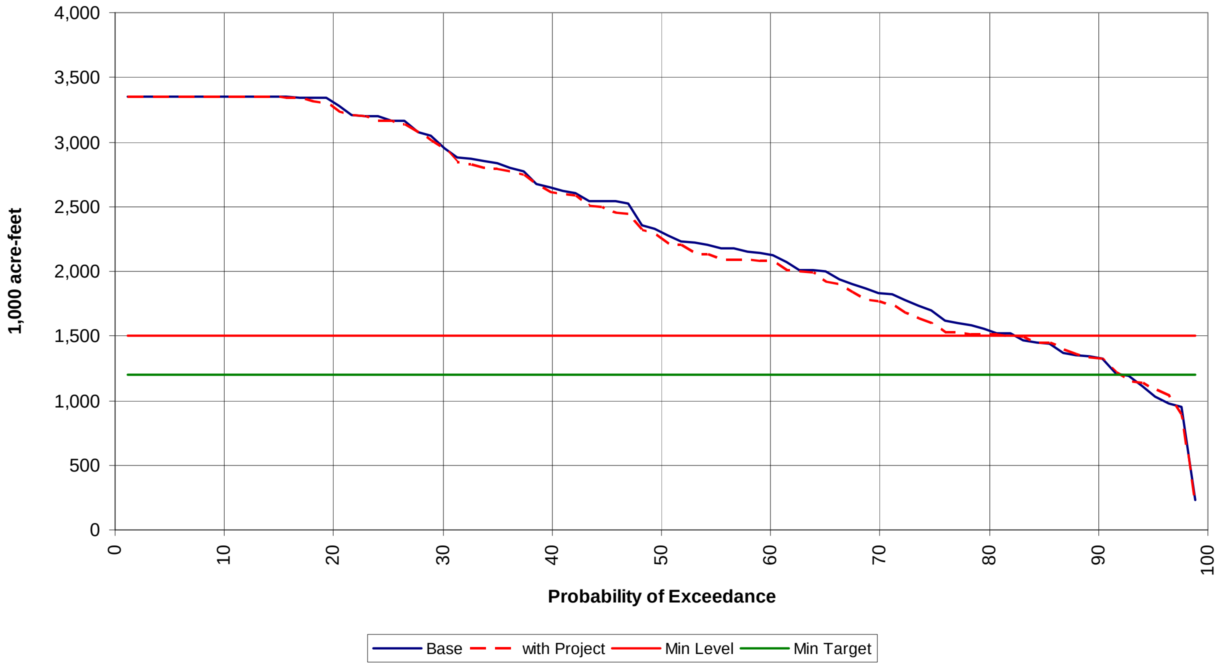


FIGURE 11-32
OROVILLE RESERVOIR SEPTEMBER STORAGE EXCEEDANCE PROBABILITY WITH CONJUNCTIVE MANAGEMENT, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figure 11-33 shows how storage space created in Oroville Reservoir through additional releases for agricultural and environmental objectives is frequently refilled with surplus surface water. This occurs in 43 years with an average annual refill of 72 TAF in those years. Average annual refill with surplus for the 82-year simulation period is approximately 36 TAF.

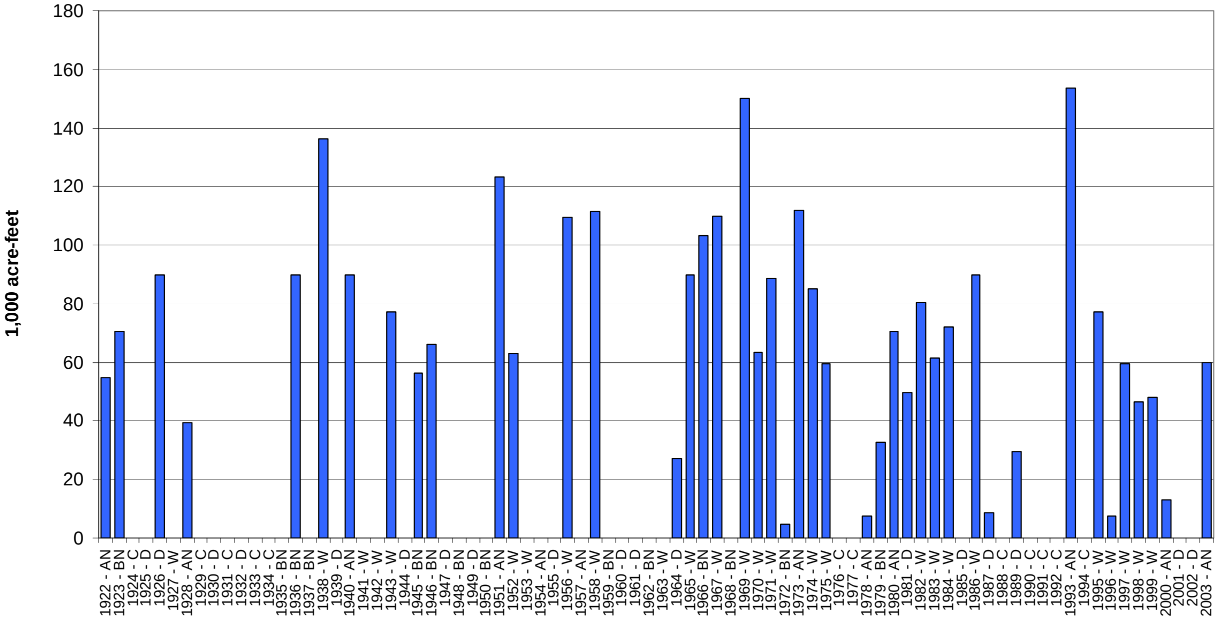


FIGURE 11-33
REFILL OF OROVILLE RESERVOIR FROM SURPLUS SURFACE WATER, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figure 11-34 presents the annual conjunctive management pumping in the Butte Basin project for Scenario 2. Conjunctive management pumping occurs in 8 of the 82 years simulated or 10 percent of the years. The average annual pumping in those years is 75 TAF. The average annual pumping for the entire 82-year simulation is approximately 7 TAF with a maximum annual pumping of the full 100 TAF of pumping capacity.

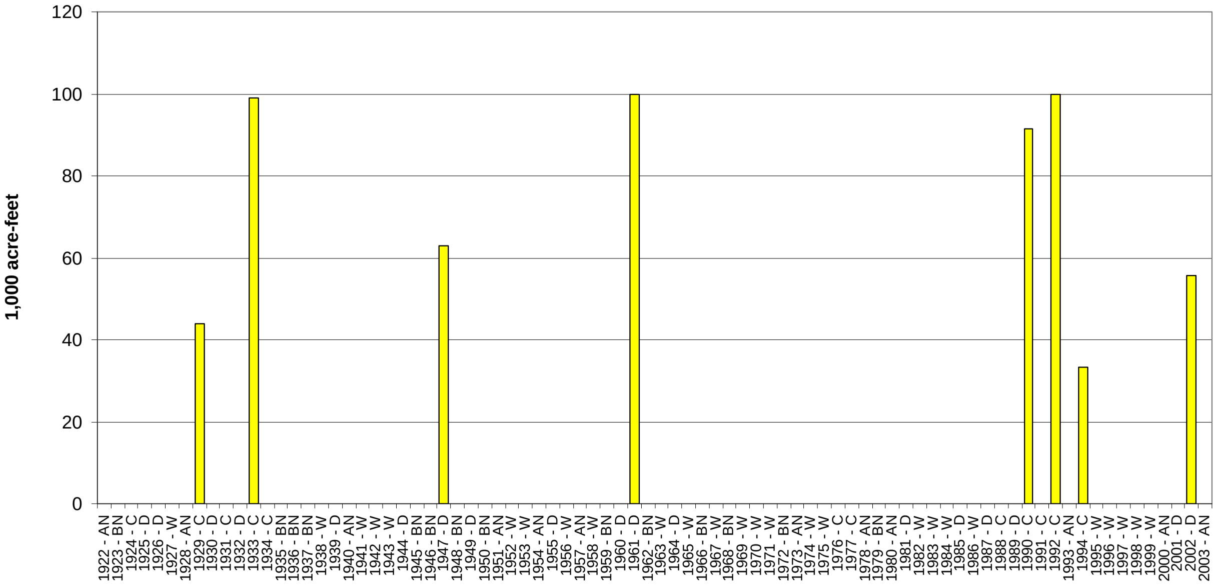


FIGURE 11-34
REFILL OF OROVILLE RESERVOIR FROM CONJUNCTIVE MANAGEMENT PUMPING, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Over the 82-year simulation period, additional reservoir releases are made in 51 years, or 62 percent of the years. Reservoir refill is accomplished with surplus surface flows in 43 years and with project pumping in 8 years. For Scenario 2 on the Feather River system, out of total additional releases of 43 TAF (23 TAF for agriculture and 20 TAF for environmental objectives), 36 TAF is refilled from surplus surface water and 7 TAF from conjunctive management pumping.

11.2.3 Groundwater Results

Existing Well Field

Results of pumping for Scenario 2 using the existing well field shown on Figure 11-3 are summarized on Figures 11-35 through 11-37. Peak drawdown in groundwater levels associated with implementation of this scenario is presented on Figure 11-35. This figure depicts simulated drawdown in the pumped aquifer, during August 1990. Maximum pumping rates under this alternative occur during 1990. Figure 11-35 shows that the area of greatest drawdown occurs in the northern GCID area at a magnitude of up to 100 feet.

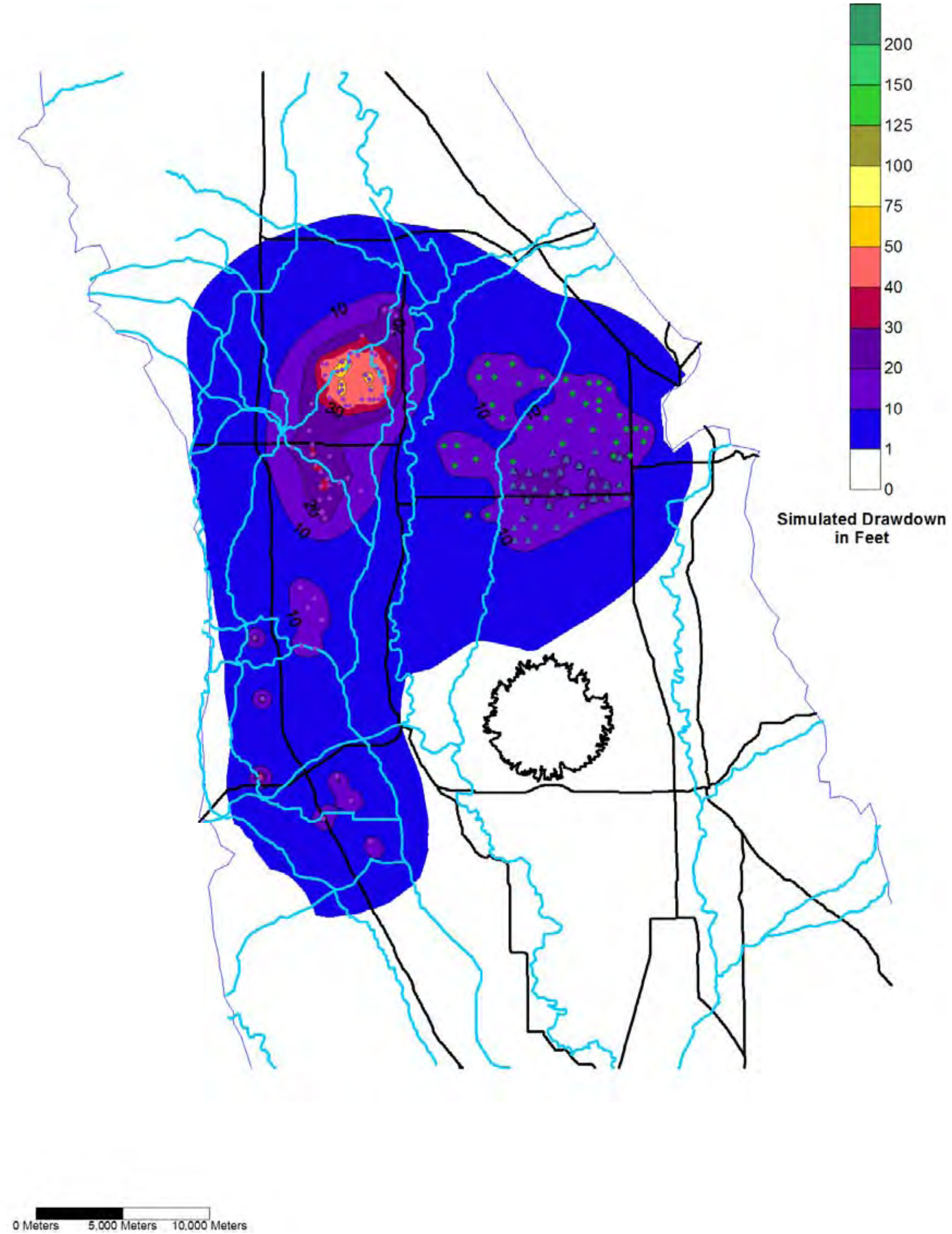


FIGURE 11-35
SIMULATED DRAWDOWN IN THE REGIONAL AQUIFER IN AUG 1990, SCENARIO 2 -EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Simulated impacts to surface streams under Scenario 2 using an existing well field are summarized on Figures 11-36 and 11-37. These figures show that the greatest impact to surface streams will occur to the Sacramento River between GCID and Wilkins Slough and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-36 suggests that the peak cumulative impact to all surface water flows will be about 110 cfs in summer of 1990, while a peak impact of just over 70 cfs is predicted to occur on the Sacramento River and a peak impact of about 32 cfs is estimated to occur on Butte Creek. Peak impact to the Sacramento River will occur in late summer of 1990 while peak impact on Butte Creek is forecast to occur in early 1993. Peak impacts to stream flows on smaller tributary streams peak at less than about 11 cfs as shown on Figure 11-37.

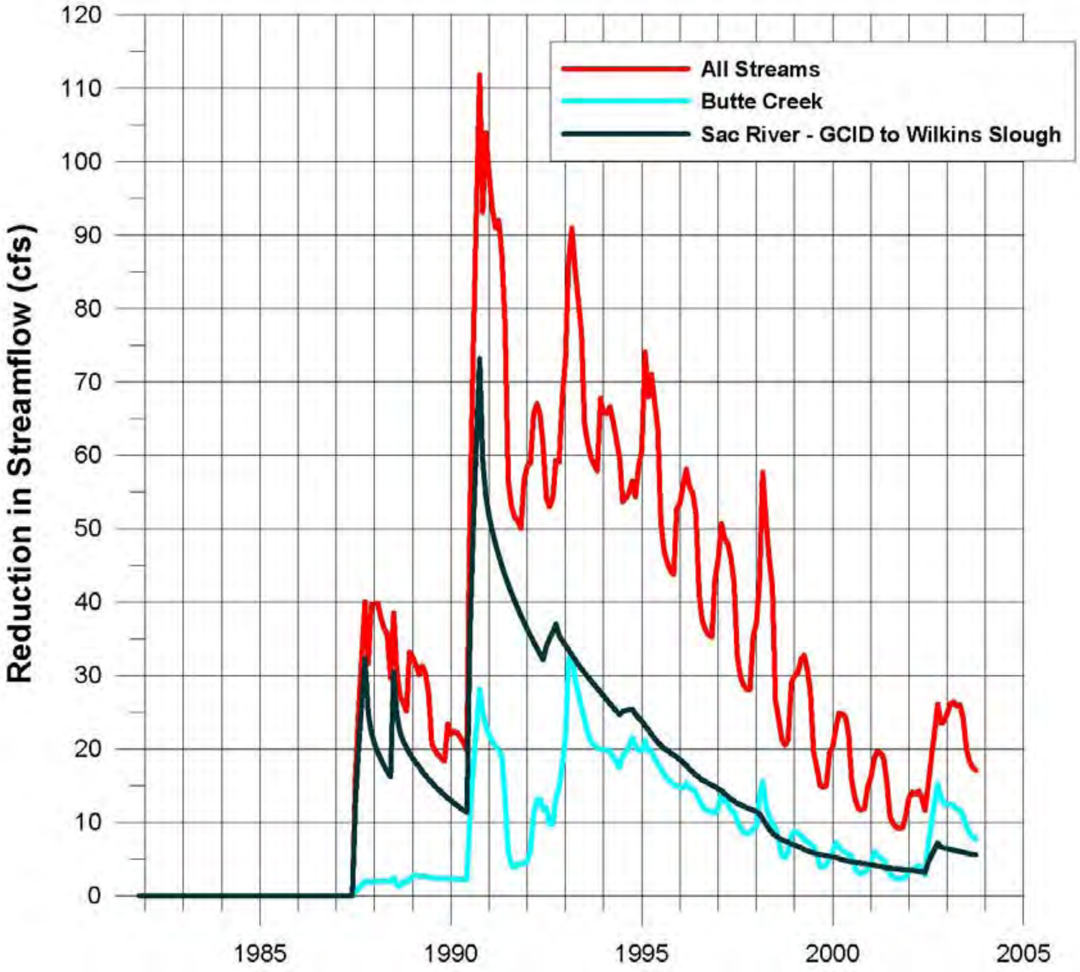


FIGURE 11-36
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 2 -EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

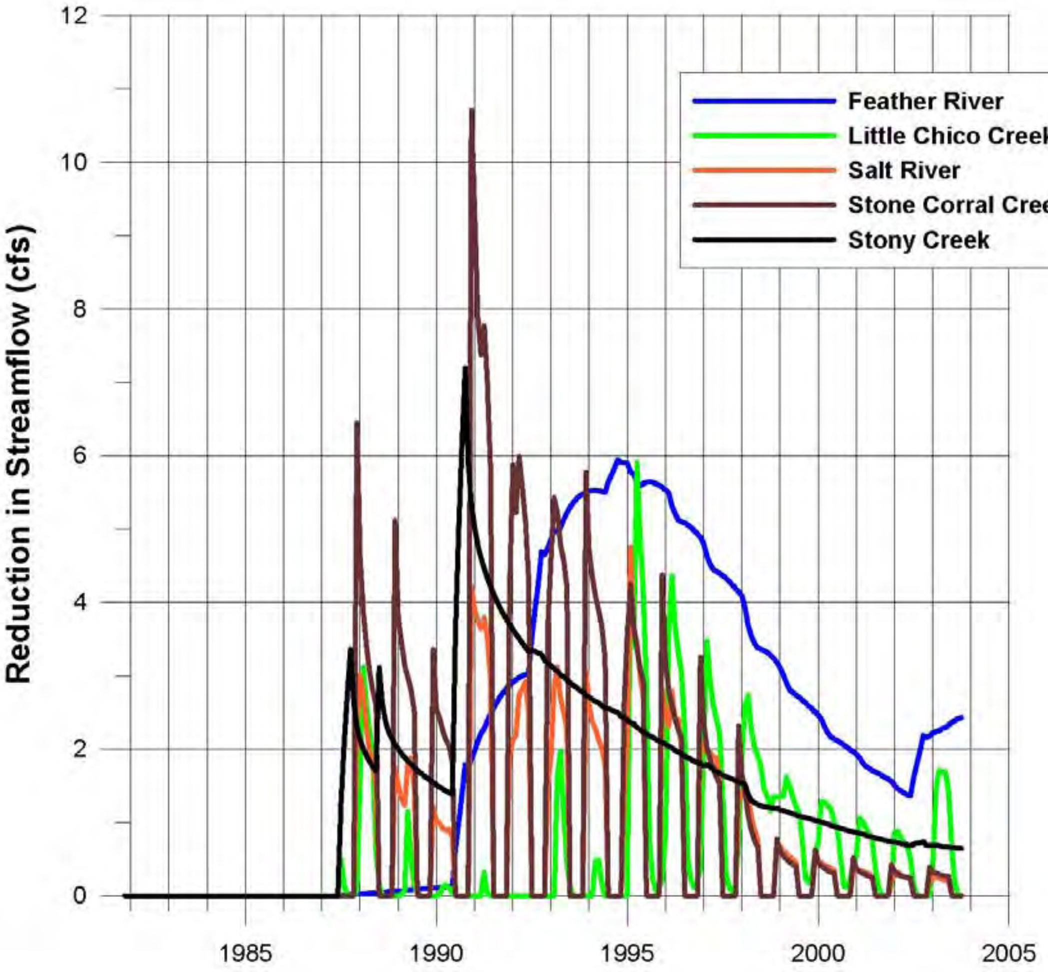


FIGURE 11-37
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 2 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

11.2.4 Reservoir Release for Recharge

Streamflow reductions, due either to increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes in upstream reservoir operations. Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions, upstream reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-38 and 11-39 present annual additional releases from Shasta and Oroville, respectively, for Scenario 2 pumping from an existing well field.

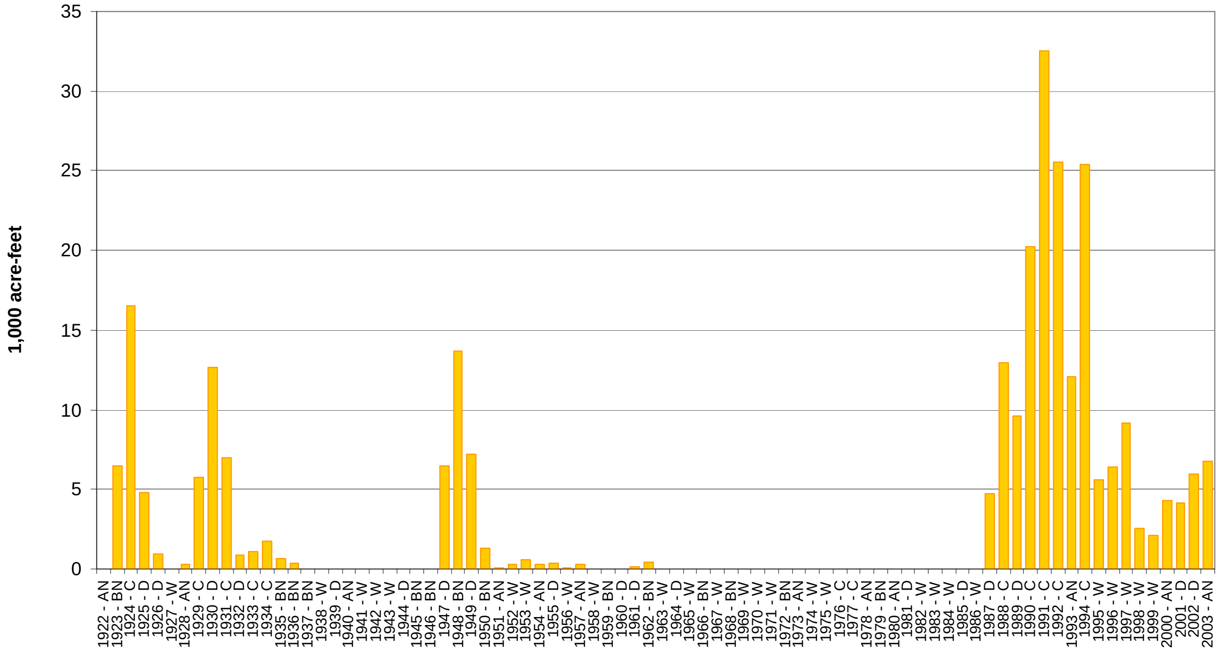


FIGURE 11-38
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 2 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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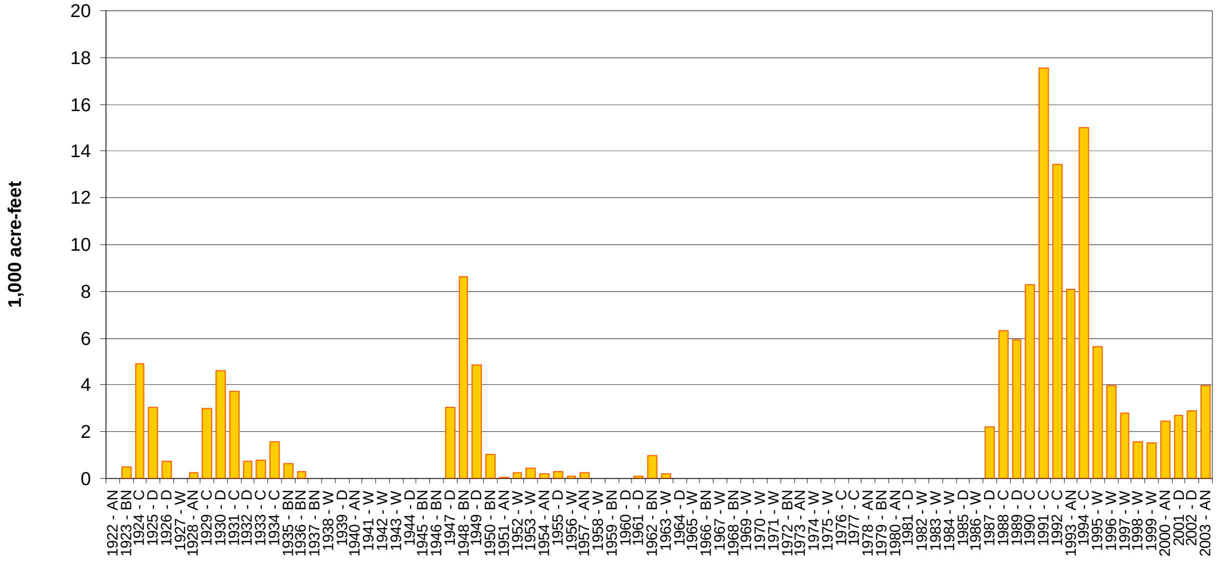

FIGURE 11-39
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 2 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Figures 11-38 and 11-39 illustrate that annual release from Shasta and Oroville to compensate for stream losses from conjunctive management pumping increase under Scenario 2 due to increased pumping frequency and quantity and the resulting increase in streamflow reductions.

New Well Field

Groundwater results for Scenario 2 using a new well field pumping from the deep aquifers are summarized on Figures 11-40 through 11-42. Peak drawdown in groundwater levels associated with implementation of this alternative is presented on Figure 11-40. This figure depicts simulated drawdown in the pumped aquifer during August 1990; the area of greatest drawdown occurs in the western GCID area at a magnitude of up to 200 feet.

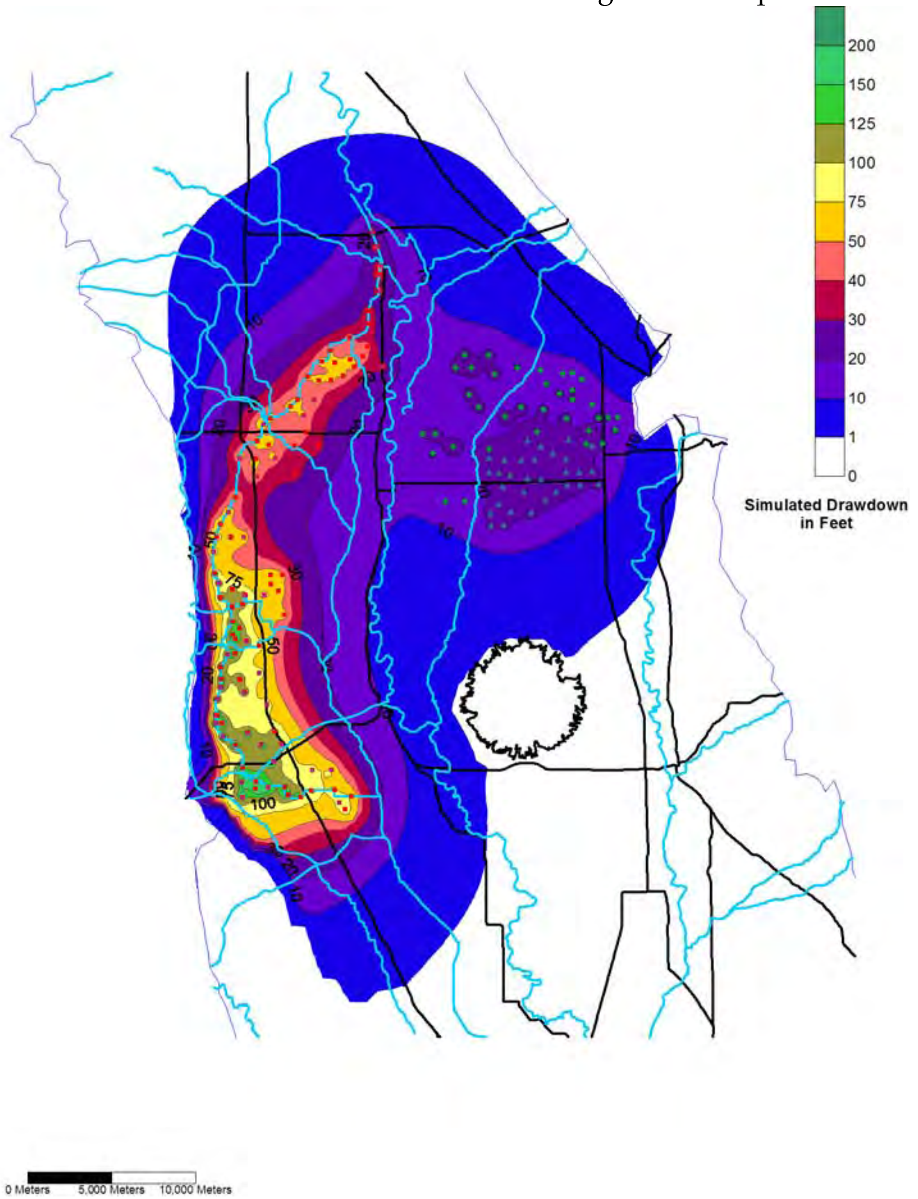

FIGURE 11-40
SIMULATED DRAWDOWN IN THE DEEP AQUIFER IN AUG 1990, SCENARIO 2 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Simulated impacts to surface streams under Scenario 2 with a new well field are summarized on Figures 11-41 and 11-42. These figures show that the greatest impact to surface streams will occur to the Sacramento River, between GCID and Wilkins Slough, and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-41 suggests that the peak cumulative impact to all surface water flows will be about 105 cfs in the late fall of 1990, and that a peak flow reduction of just less than 70 cfs will occur on the Sacramento River while a peak flow reduction of about 27 cfs will occur on Butte Creek. Peak impact to the Sacramento River will also occur in late fall of 1990 while two similar peak impacts occur on Butte Creek in early 1993 and the fall of 1994. Impacts to stream flows on smaller tributary streams peak at less than about 15 cfs, as shown on Figure 11-41.

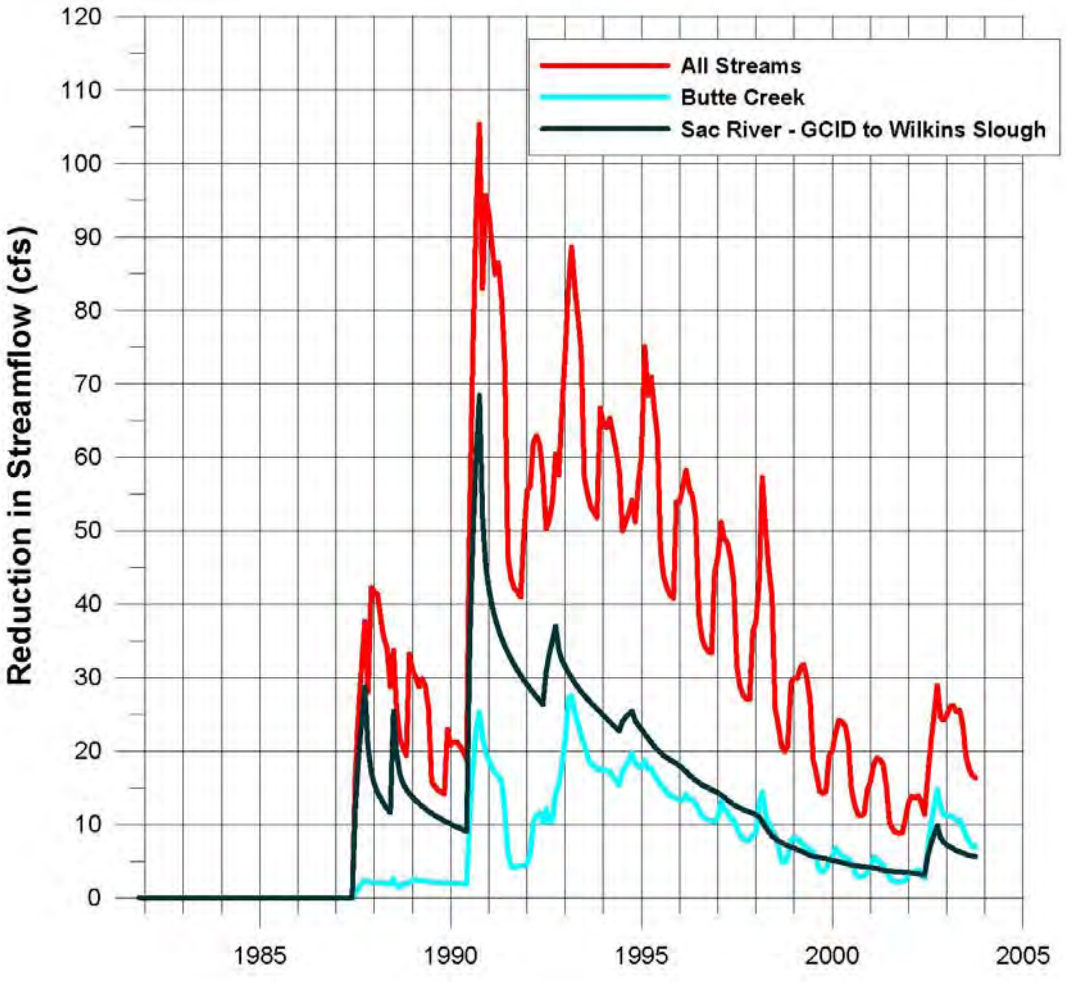

FIGURE 11-41
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 2 -NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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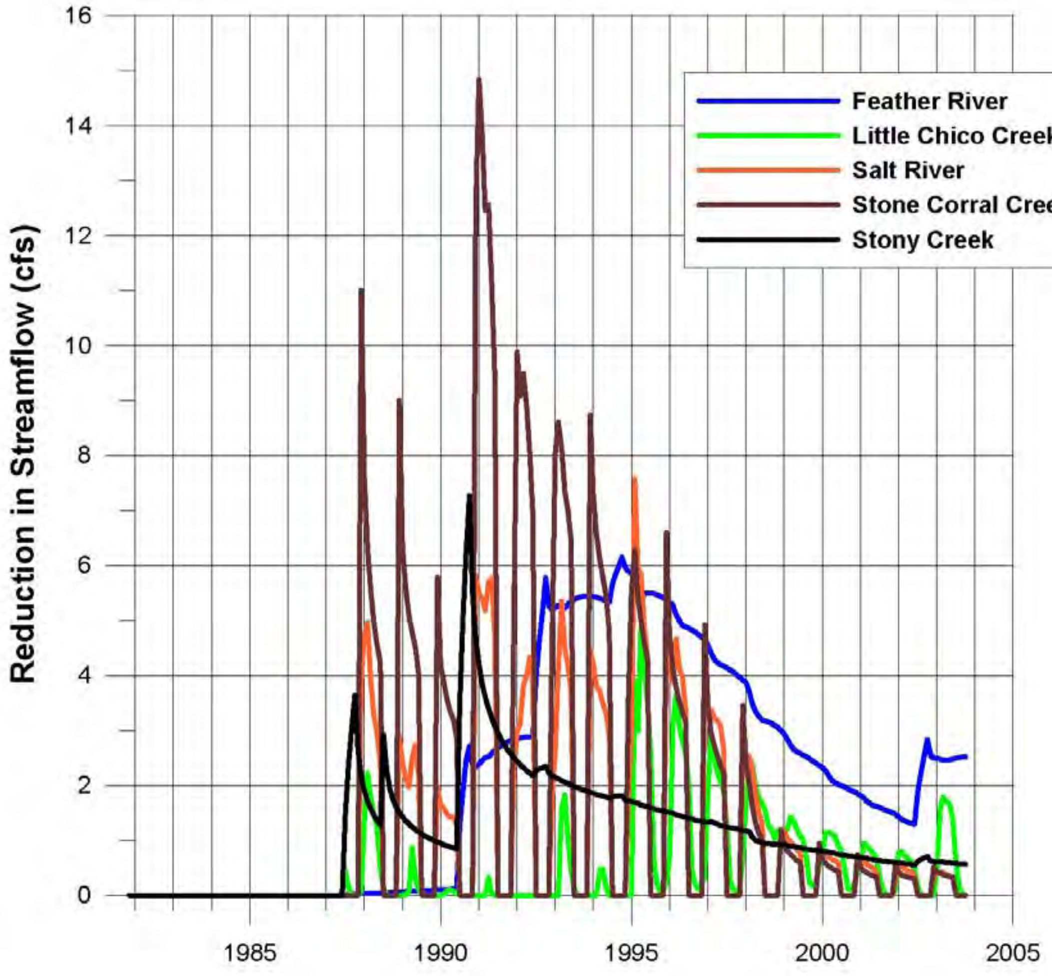

FIGURE11-42
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 2 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Reservoir Release for Recharge

Streamflow reductions, due to either increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes to upstream reservoir operations. Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions upstream, reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-43 and 11-44 present annual additional releases from Shasta and Oroville, respectively, for Scenario 2 pumping from a new well field.

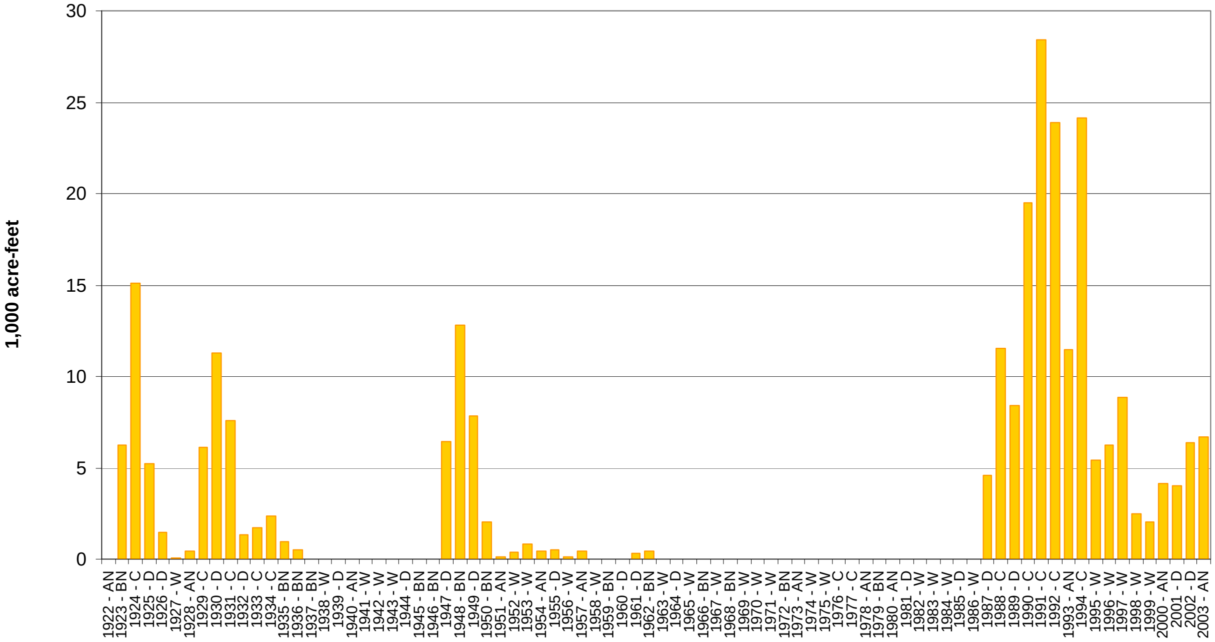

FIGURE 11-43
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 2 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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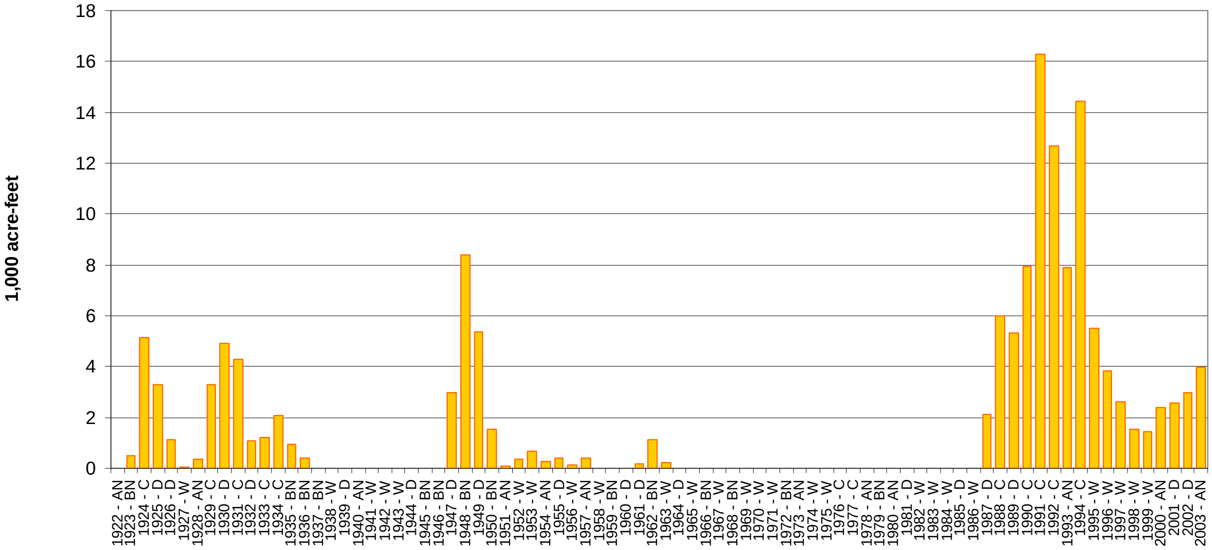

FIGURE 11-44
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 2 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Figures 11-43 and 11-44 show smaller peak reservoir releases to compensate for conjunctive management pumping for a new well field screen in the deep aquifer than for pumping existing wells. This reflects smaller streamflow reductions for a new well field at the higher pumping volumes simulated in Scenario 2.

11.3 Scenario 3 – 100 TAF GCID, 50 TAF Butte Basin, Fall Pumping

Scenario 3 has the same general reservoir release strategies and groundwater pumping capacities as Scenario 1. The difference is the season for conjunctive management pumping. Under Scenario 3 conjunctive management pumping for the purpose of recovering reservoir storage levels is conducted from September through November. Instead of offsetting irrigation season demands, this pumping is assumed to offset demands for rice straw decomposition and waterfowl habitat.

Shifting the conjunctive management pumping season may have several benefits. First, peak drawdown in the aquifers and resulting effects on nearby wells would occur outside of the primary pumping season for most existing wells. Second, a greater portion of aquifer recharge may occur during the winter rainy season when the surface water system is more likely to be in a surplus condition. Third, it may be easier to reduce fall reservoir releases to recover reservoir levels in the fall of dry years and still meet existing temperature control criteria on the Sacramento River.

A majority of results for Scenario 3 are the same as for Scenario 1 because spring and summer surface water operations do not change. The same environmental objectives are met, and the average annual releases for both environmental and agricultural objectives are the same. Reservoir refill for both Shasta and Oroville occurs with the same mix and timing of surplus surface water and groundwater pumping. There are minor differences in end of September storage in each reservoir under Scenario 3. These differences are in years when conjunctive management pumping occurs, but is not yet complete, by the end-of-September. Figures 11-45 and 11-46 illustrate this effect for both Shasta and Oroville.

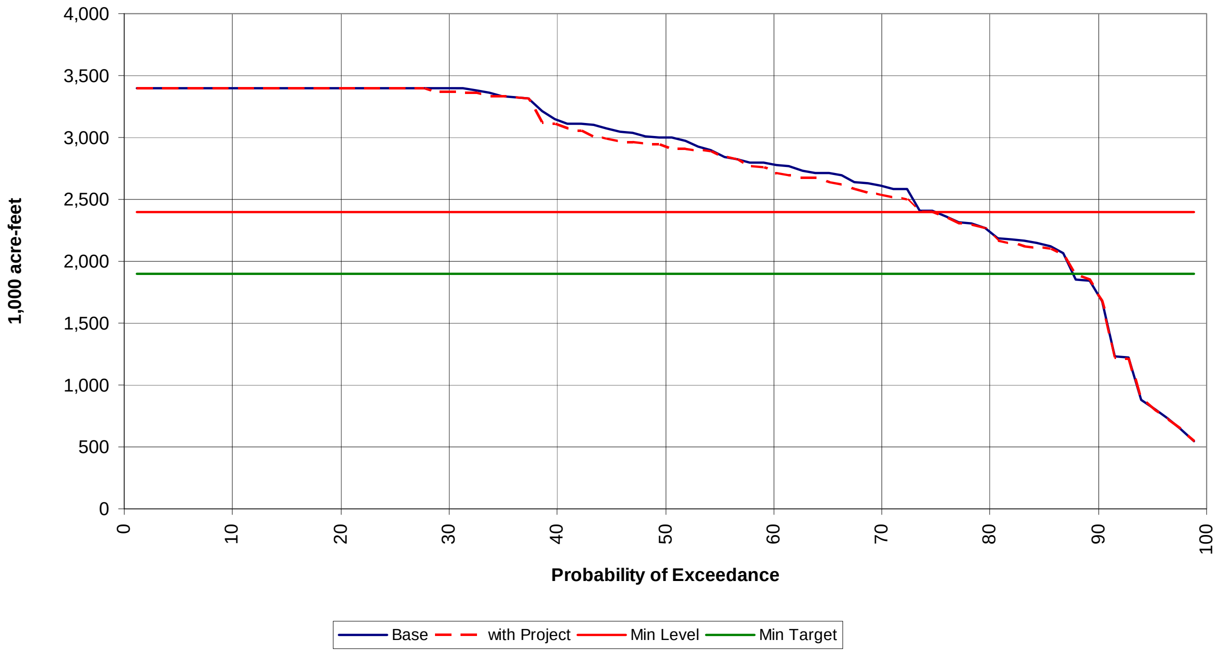

FIGURE 11-45
SHASTA RESERVOIR SEPTEMBER STORAGE EXCEEDANCE PROBABILITY WITH CONJUNCTIVE MANAGEMENT, SCENARIO 3
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 11-45 shows some minor differences between base conditions and Scenario 3 when end-of-September Shasta storage levels are below 2,400 TAF. In these years, conjunctive management pumping is occurring September through November so that the reservoir is recovered by the end of November and there is no risk to future water supplies or cold water pool.

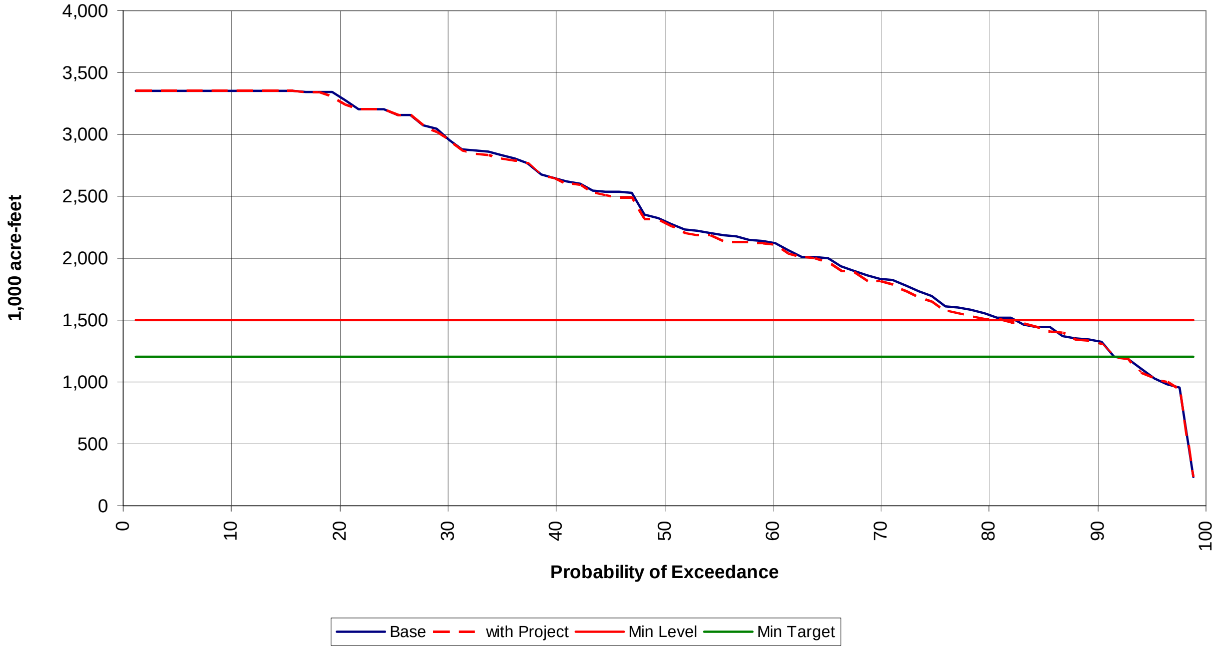

FIGURE 11-46
OROVILLE RESERVOIR SEPTEMBER STORAGE EXCEEDANCE PROBABILITY WITH CONJUNCTIVE MANAGEMENT, SCENARIO 3
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Figure 11-46 illustrates a similar effect on Oroville Reservoir, but it is less clear due to the smaller difference between base and with project storages.

11.3.1 Groundwater Results

Existing Well Field

Results of pumping for Scenario 3 with an existing well field are summarized on Figures 11-47 through 11-49. Peak drawdown in groundwater levels associated with implementation of this alternative is presented on Figure 11-47. This figure depicts simulated drawdown in the pumped aquifer during November 1990. Maximum pumping rates under this alternative occur during 1990. Figure 11-47 shows that the area of greatest drawdown occurs in the northern GCID area at a magnitude of up to 50 feet.

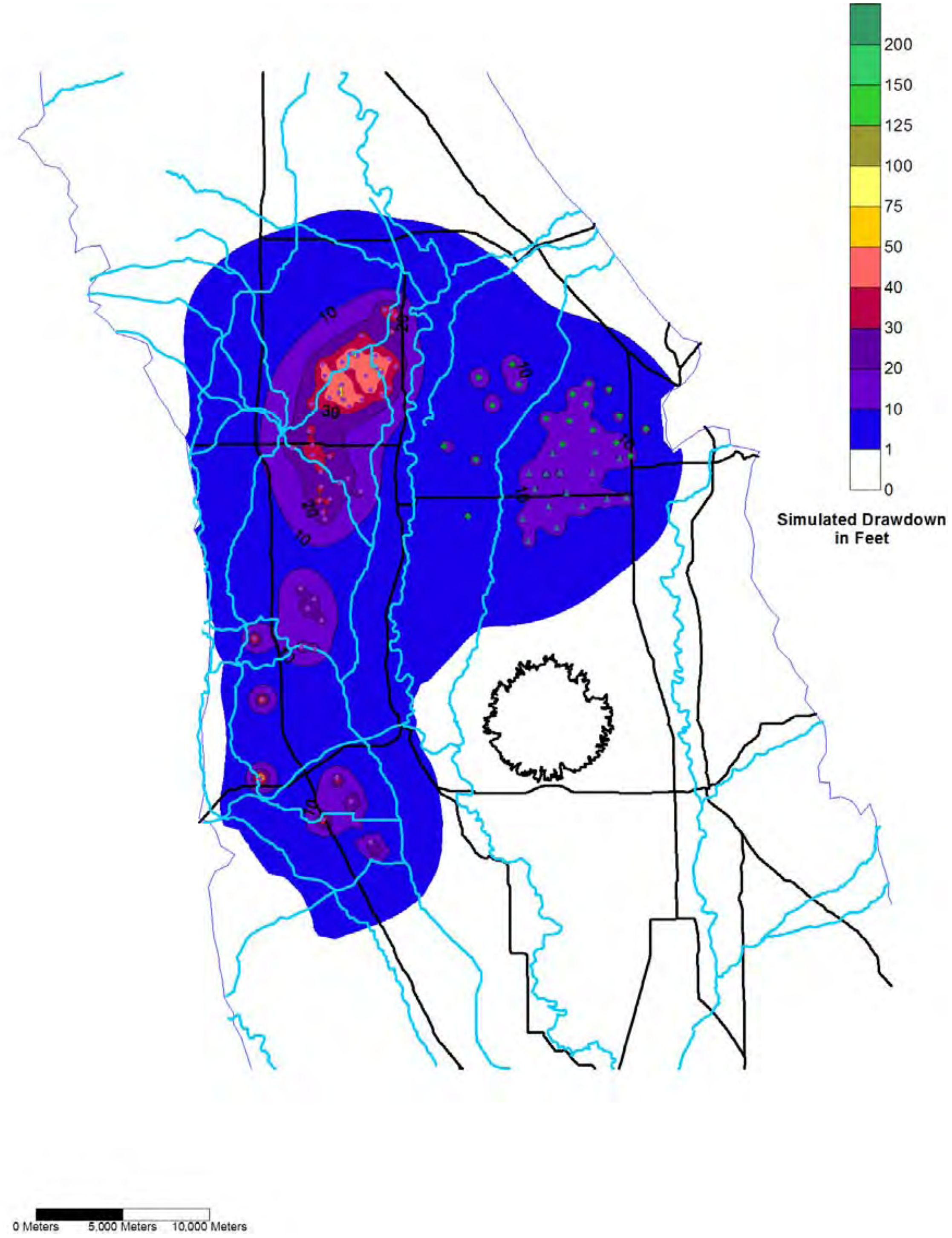

FIGURE 11-47
SIMULATED DRAWDOWN IN THE REGIONAL AQUIFER IN NOV 1990, SCENARIO 3 -EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Simulated impacts to surface streams under Scenario 3 with an existing well field are summarized on Figures 11-48 and 11-49. These figures show that the greatest impact to surface streams will occur to the Sacramento River (between GCID and Wilkins Slough) and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-48 suggests that peak cumulative impact to all surface water flows will be approximately 80 cfs in the summer of 1990, with a flow reduction of approximately 50 cfs forecast to occur on the Sacramento River and a flow reduction of approximately 18 cfs on Butte Creek. Peak impact to the Sacramento River will also occur in late summer of 1990 while peak impact on Butte Creek is forecasted to occur in late 1994. Peak impacts to stream flows on smaller tributary streams peak at less than approximately 7 cfs, as shown on Figure 11-48.

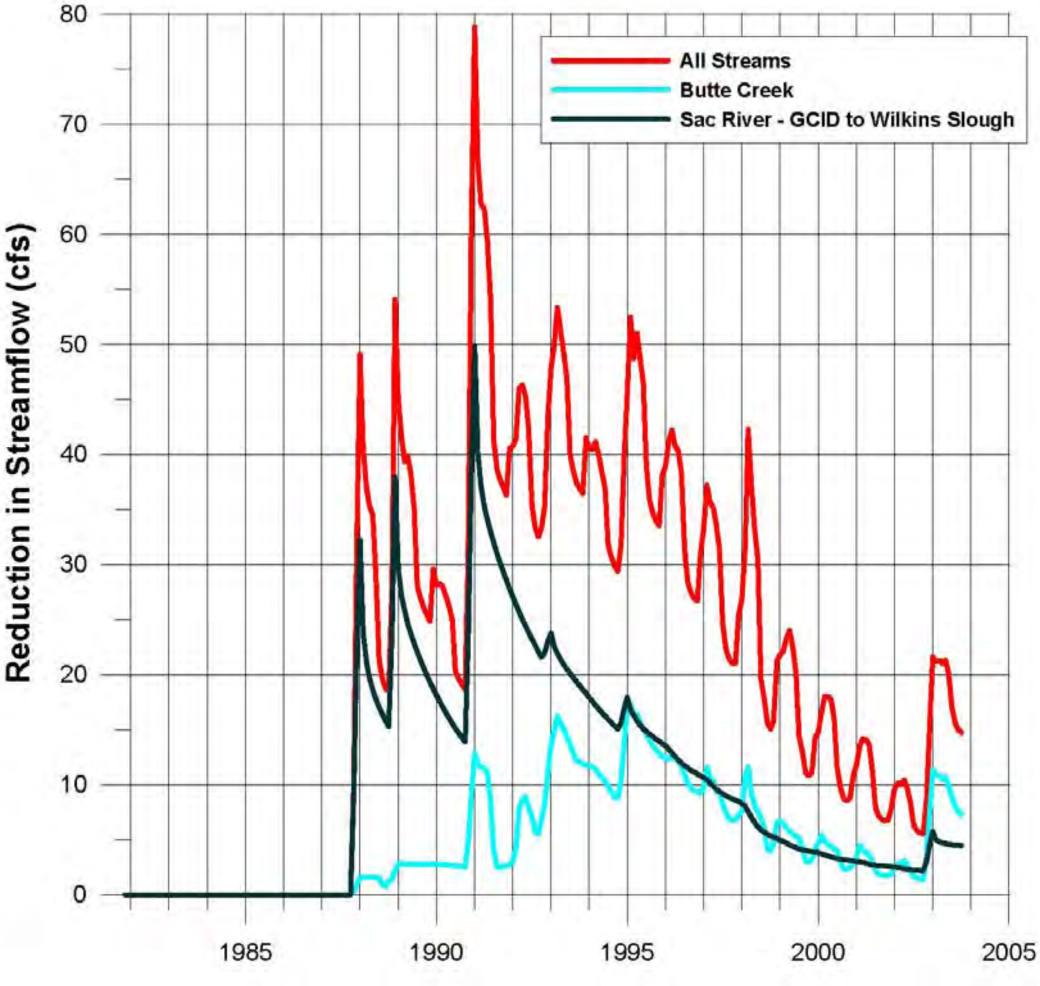

FIGURE 11-48
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 3 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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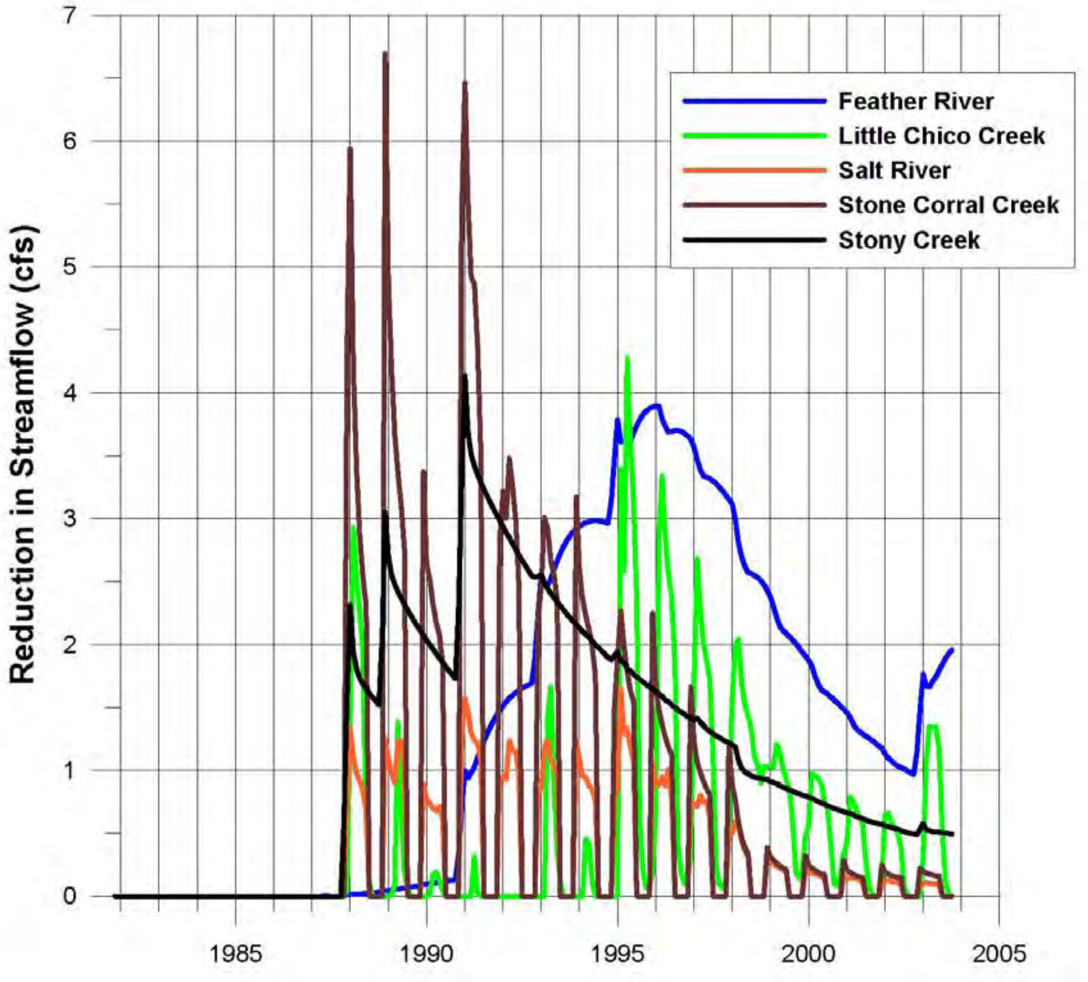

FIGURE 11-49
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 3 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Reservoir Release for Recharge

Streamflow reductions, due to either increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes to upstream reservoir operations. Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions, upstream reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-50 and 11-51 present annual additional releases from Shasta and Oroville, respectively, for Scenario 3 pumping from an existing well field.

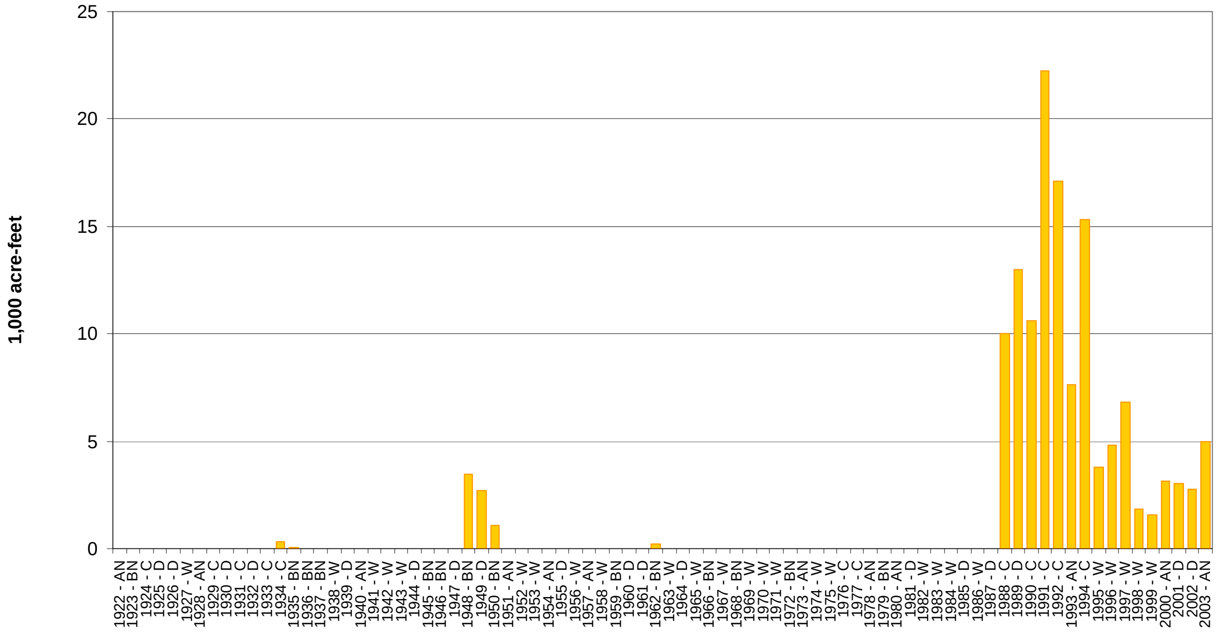

FIGURE 11-50
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 3 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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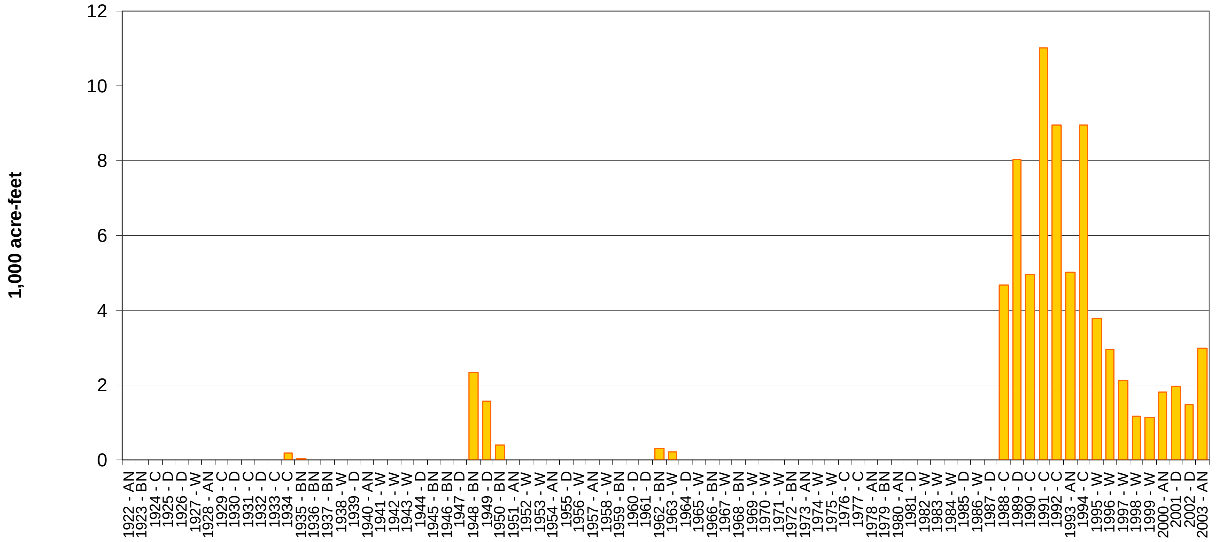

FIGURE 11-51
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 3 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Figures 11-50 and 11-51 show that peak annual releases are larger under Scenario 3 for the more condensed fall pumping season than under Scenario 1. General timing and volumes are similar between the two scenarios.

New Well Field

Results of Scenario 3 with a new well field are summarized on Figures 11-52 through 11-54. The peak drawdown in groundwater levels associated with the implementation of this alternative is presented on Figure 11-52. This figure depicts the simulated drawdown in the pumped aquifer, during November 1990. The maximum pumping rates under this alternative occur during 1990. It can be seen from the figure that the area of greatest drawdown occurs in the western GCID area at a magnitude of up to 125 feet.

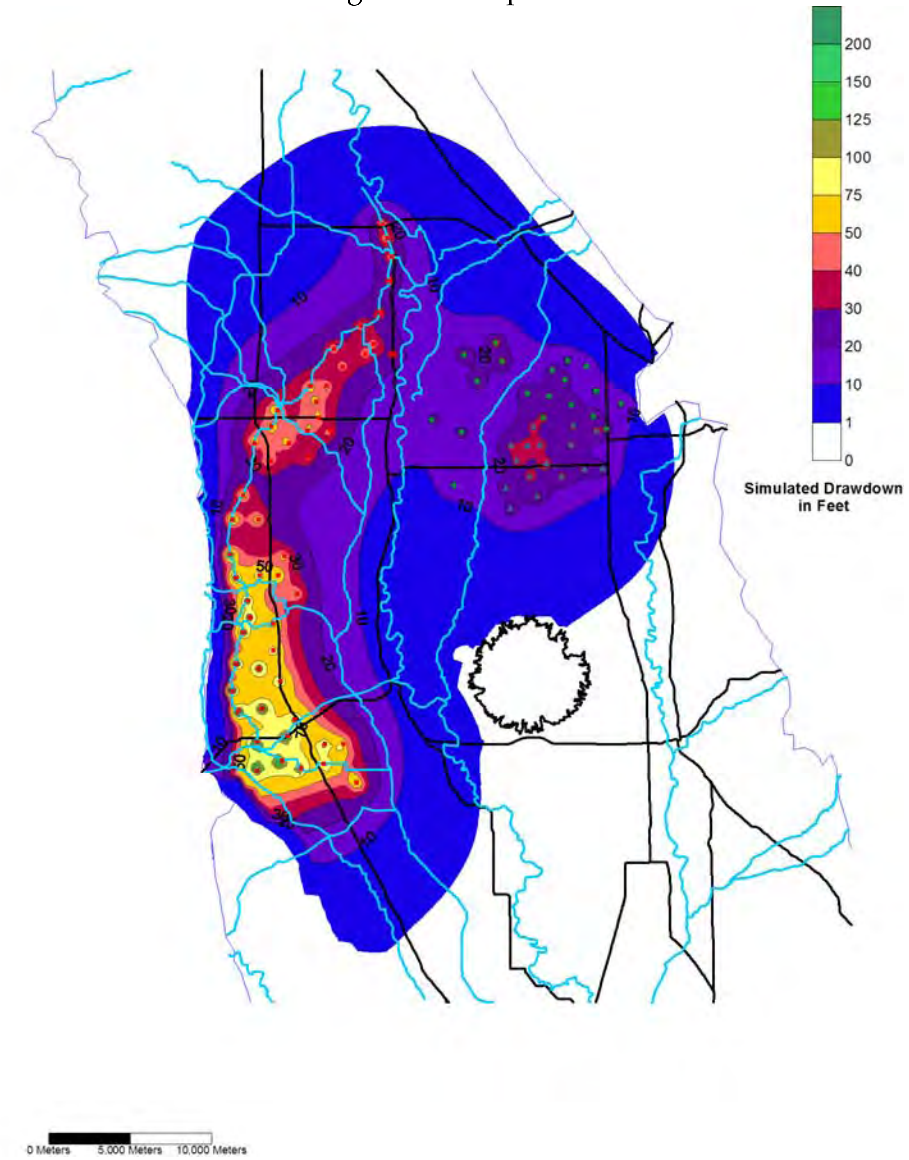

FIGURE 11-52
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 3 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Simulated impacts to surface streams under Scenario 3 with a new well field are summarized on Figures 11-53 and 11-54. These figures show that the greatest impact to surface streams will occur to the Sacramento River, between GCID and Wilkins Slough, and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-44 suggests that the peak cumulative impact to all surface water flows will be a reduction of about 90 cfs in December 1990, while a flow reductions of just more than 48 and 18 cfs is forecasted to occur on the Sacramento River and Butte Creek, respectively. Peak impact to the Sacramento River will also occur in December 1990 while peak impact predicted on Butte Creek will occur in December 1994. Peak impacts to stream flows on smaller tributary streams peak at less than about 10 cfs as shown on Figure 11-54.

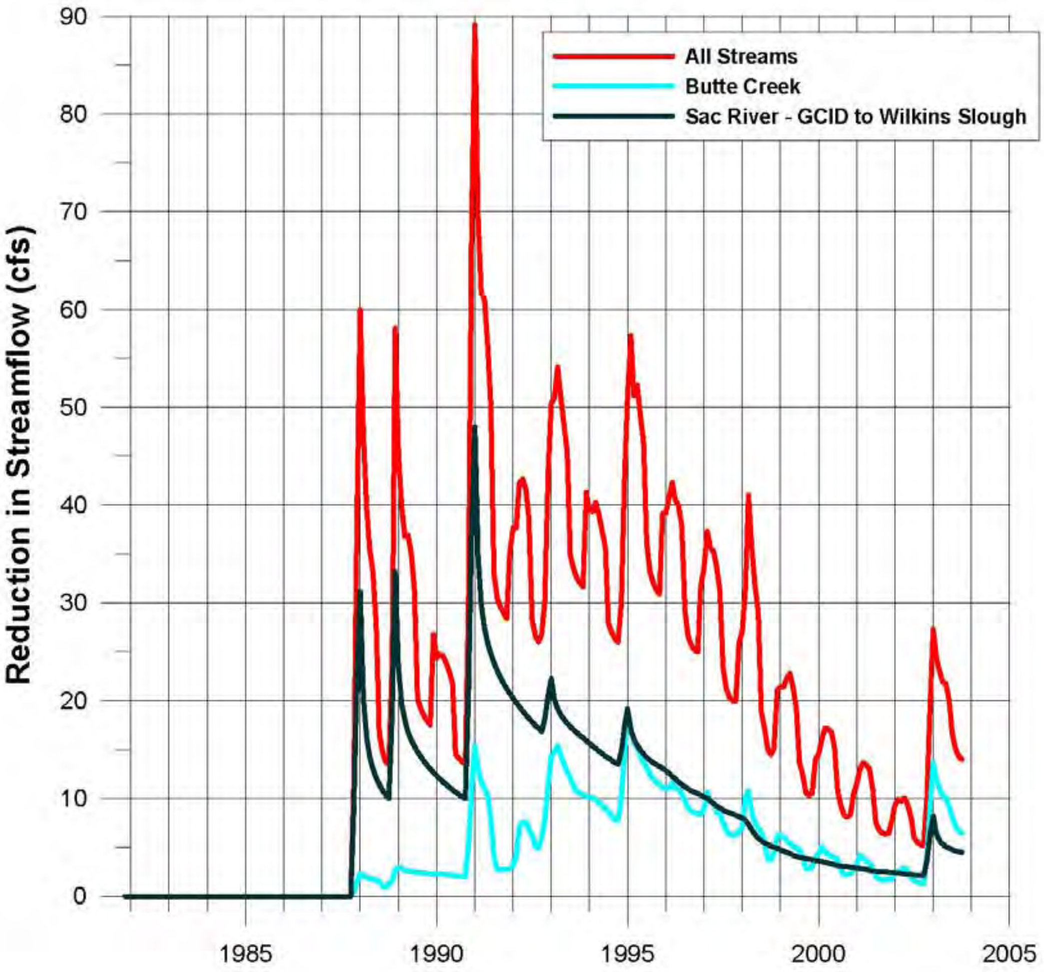

FIGURE 11-53
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 3 -NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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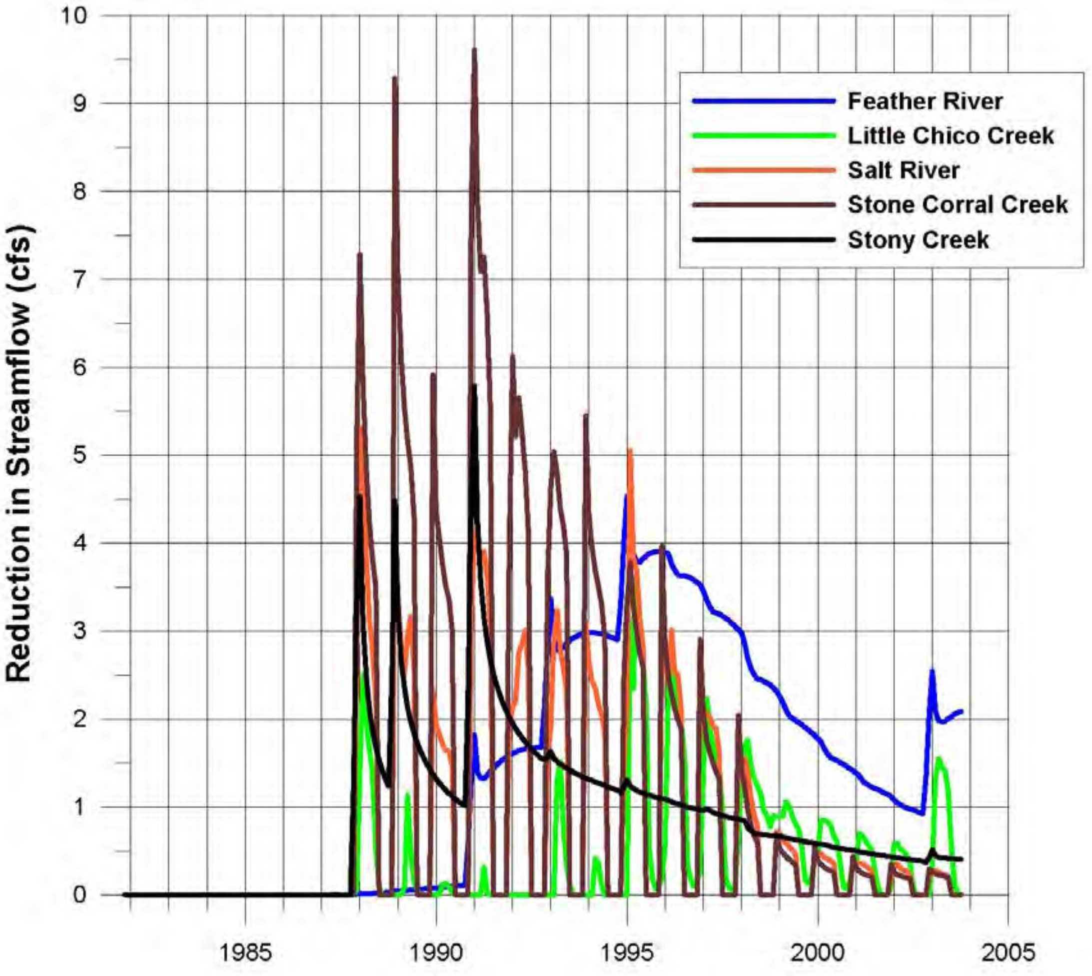

FIGURE 11-54
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 3 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Reservoir Release for Recharge

Streamflow reductions, due either to increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes in upstream reservoir operations. Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions upstream reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-55 and 11-56 present annual additional releases from Shasta and Oroville, respectively, for Scenario 3 pumping from a new well field.

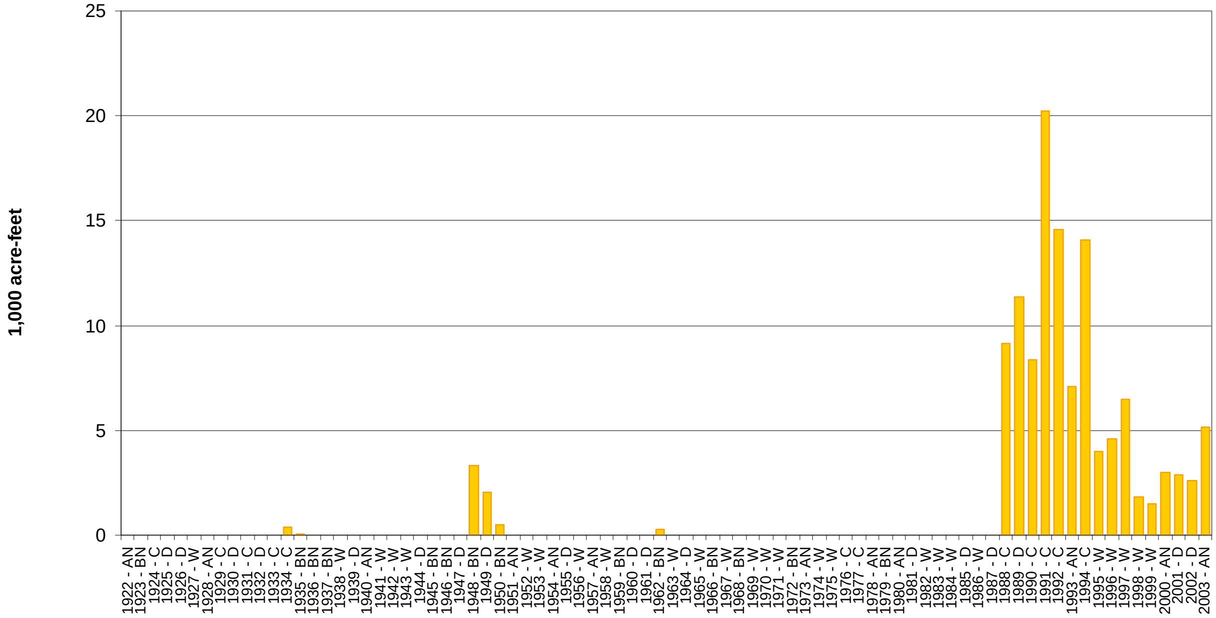

FIGURE 11-55
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 3 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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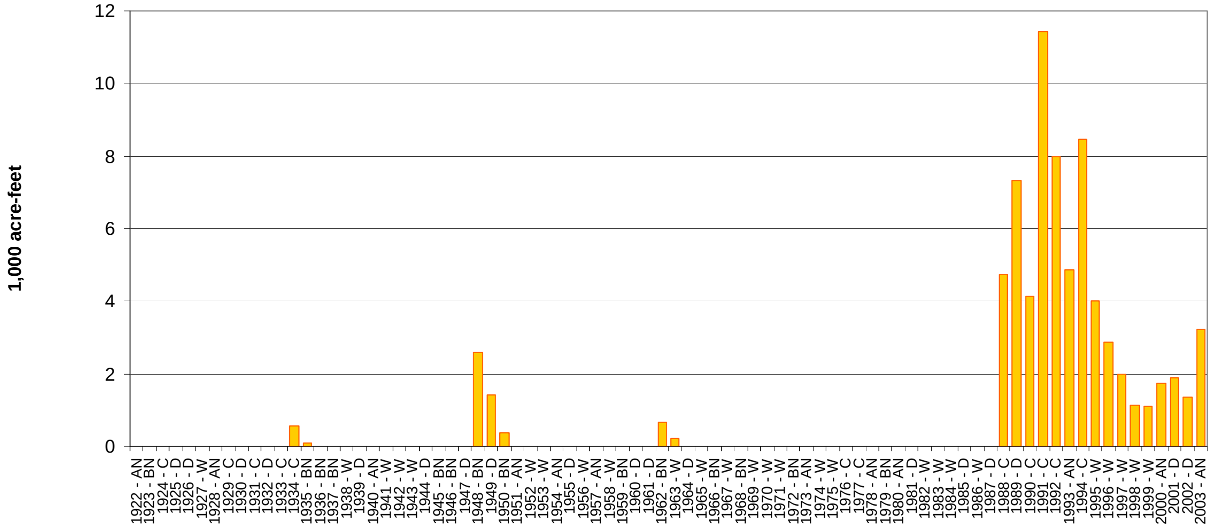

FIGURE 11-56
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 3 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
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Figures 11-54 and 11-55 illustrate that maximum annual release from Shasta for a new well field is less than for the existing well field, while results are essentially the same on the Feather River.

11.4 Scenario 4 – 100 TAF GCID, 50 TAF Butte Basin, Summer and Fall Pumping

Scenario 4 has the same general reservoir release strategies and groundwater pumping capacities as Scenarios 1 and 3. The difference is again the season for conjunctive management pumping. Under Scenario 4 conjunctive management pumping is conducted in both the summer and fall from May through November. This pumping is used to offset both irrigation season demands and demand for rice straw decomposition water. Pumping over an extended period may provide benefits by reducing the quantity of water that must be pumped in any given month, thereby reducing the size and/or number of wells needed. Additionally, spreading pumping over a longer period may reduce drawdown and stream impacts.

Surface water results for Scenario 4 are similar to those presented for Scenario 1. The same environmental objectives are met, and the average annual releases for both environmental and agricultural objectives are the same. Reservoir refill for both Shasta and Oroville occurs with the same mix and timing of surplus surface water and groundwater pumping. Changes in end-of September storage in the reservoirs presented above for Scenario 3 are smaller in magnitude because under Scenario 4 the majority of conjunctive management pumping has occurred prior to the end of September. The minor differences seen under Scenario 4 are difficult to discern and are therefore not presented.

11.4.1 Existing Well Field

Results for Scenario 4 with an existing well field are summarized on Figures 11-57 through 11-58. Peak drawdown in groundwater levels associated with implementing this alternative is presented on Figure 11-57. This figure depicts simulated drawdown in the pumped aquifer, during November 1990. Maximum pumping rates under this alternative occur during 1990, and the drawdown distribution at the end of November represents approximately the maximum drawdown that will occur under this scenario. Figure 11-57 that the area of greatest drawdown occurs in northern GCID at a magnitude of less than 30 feet.

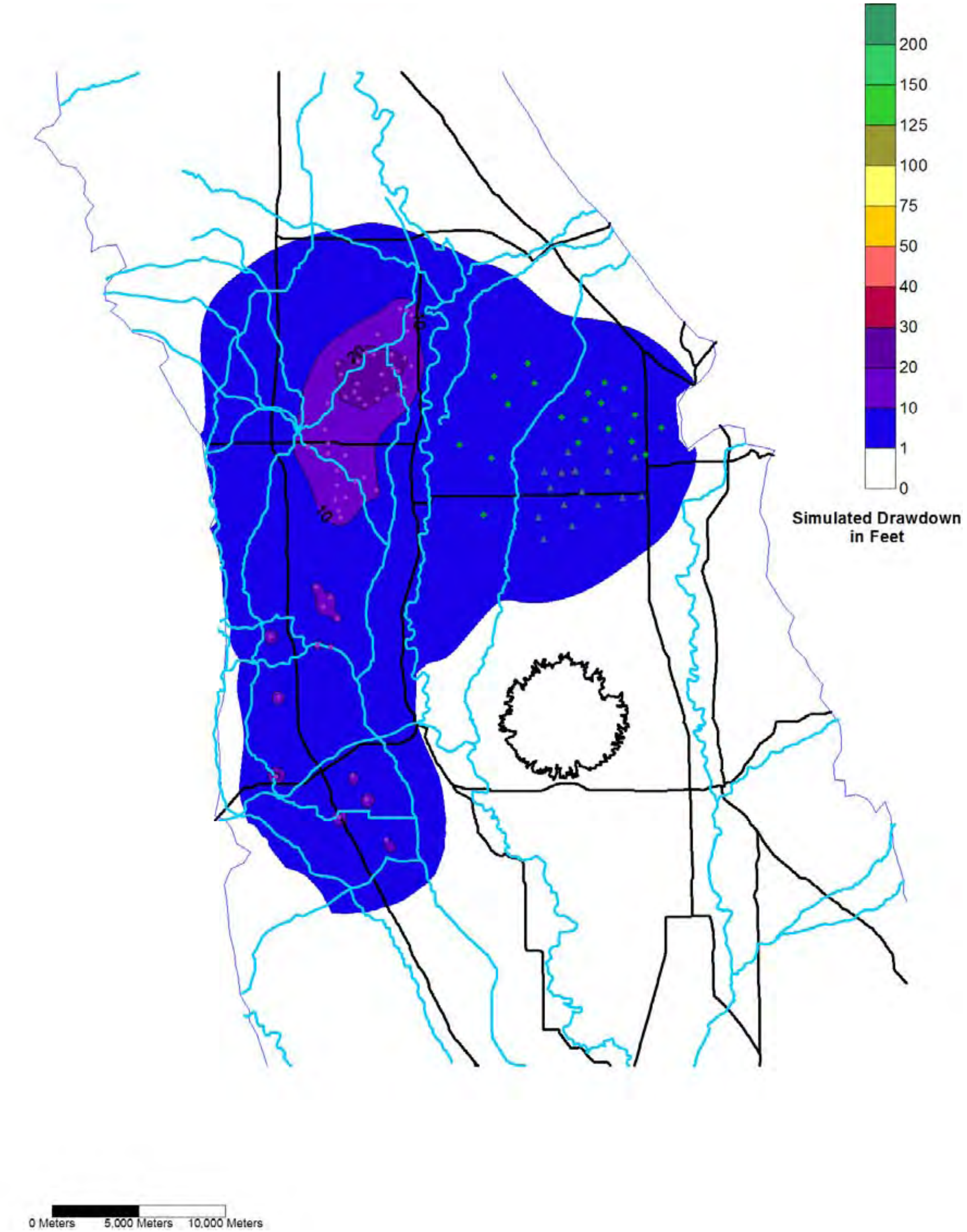


FIGURE 11-57
SIMULATED DRAWDOWN IN THE REGIONAL AQUIFER IN NOV 1990, SCENARIO 4 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Simulated impacts to surface streams under Scenario 4 with an existing well field are summarized on Figures 11-58 and 11-59. These figures show that the greatest impact to surface streams will occur to the Sacramento River, between GCID and Wilkins Slough, and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-58 shows that the peak cumulative impact to all surface water flows will be approximately 64 cfs in December 1990, with a flow reduction of just less than 40 cfs forecasted to occur on the Sacramento River and a flow reduction of about 15 cfs on Butte Creek. Peak impact to the Sacramento River will also occur in December of 1990 while the peak impact on Butte Creek is forecast to occur in late 1995. Peak impacts to stream flows on smaller tributary streams peak at less than approximately 6 cfs, as shown on Figure 11-59.

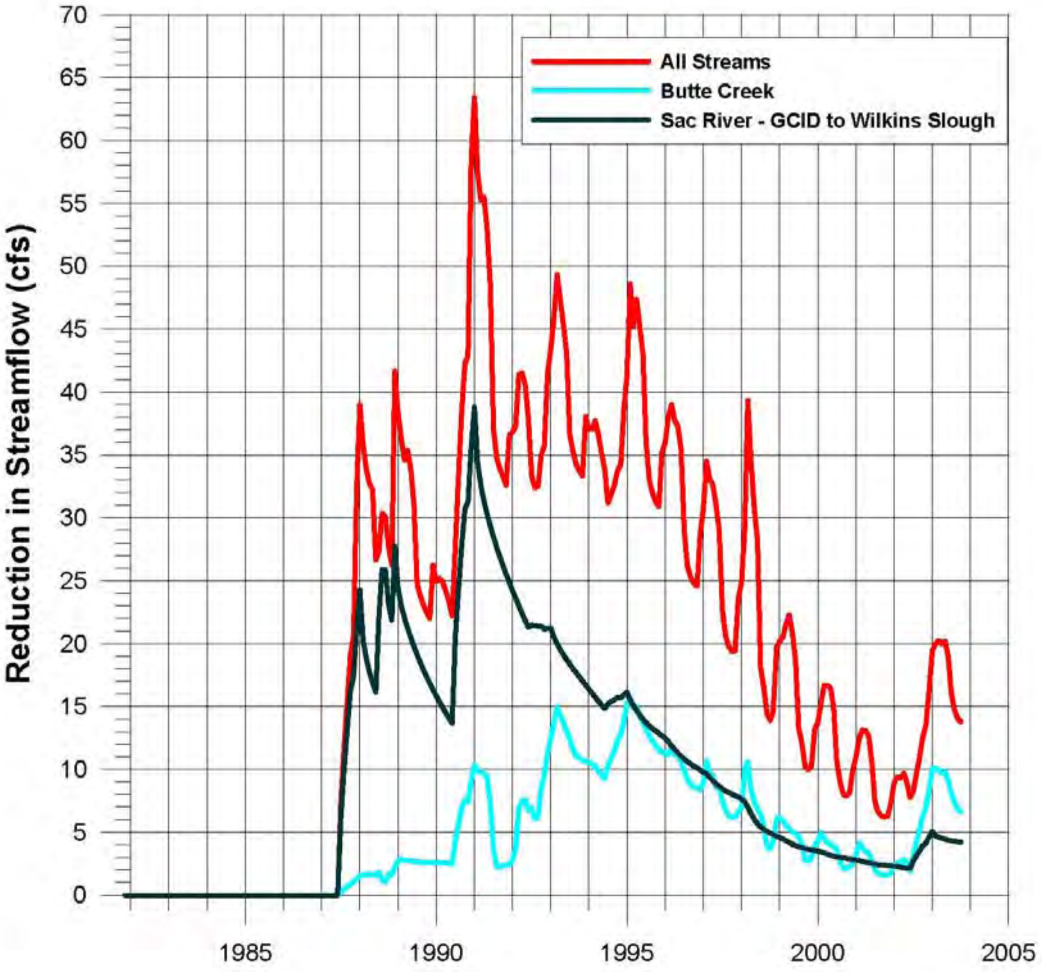


FIGURE 11-58
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 4 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

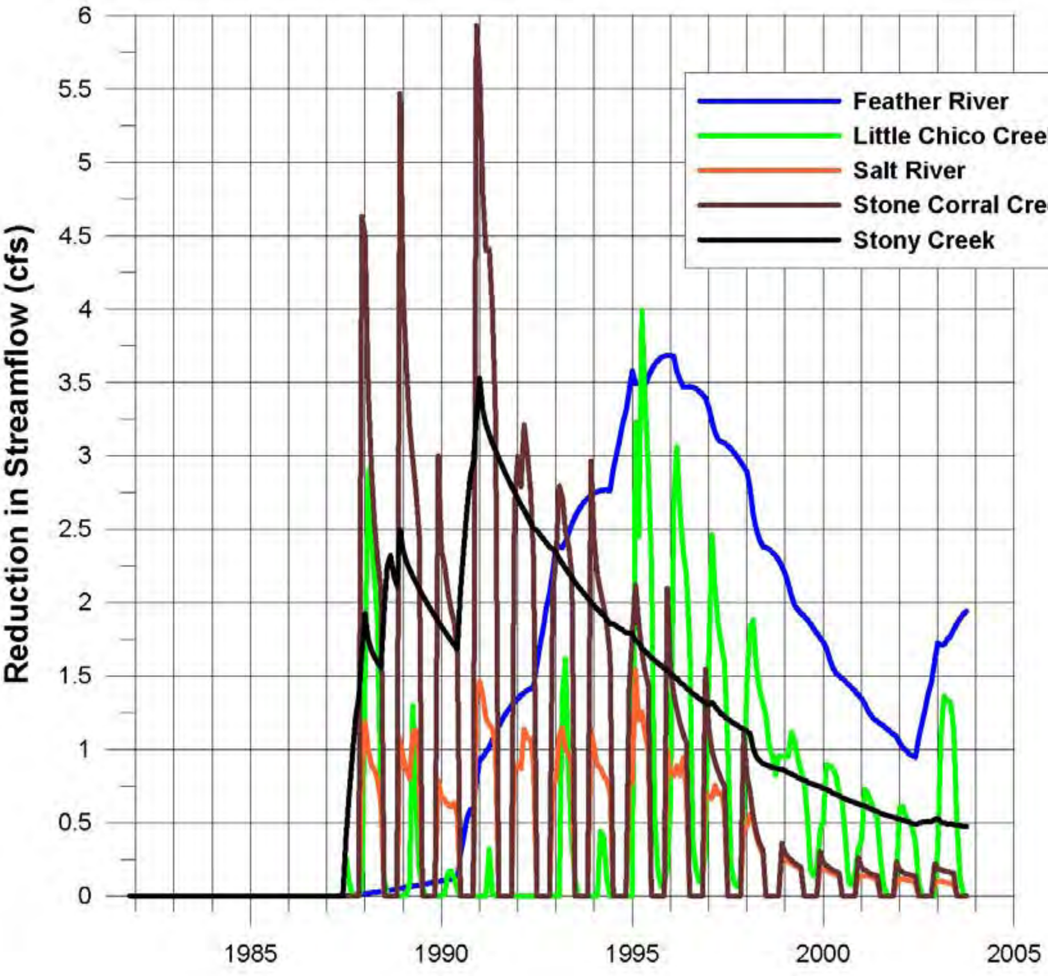


FIGURE 11-59
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 4 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

11.4.2 Reservoir Release for Recharge

Streamflow reductions, due to either increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes in upstream reservoir operations. Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions upstream, reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-60 and 11-61 present annual additional releases from Shasta and Oroville, respectively, for Scenario 4 pumping from an existing well field.

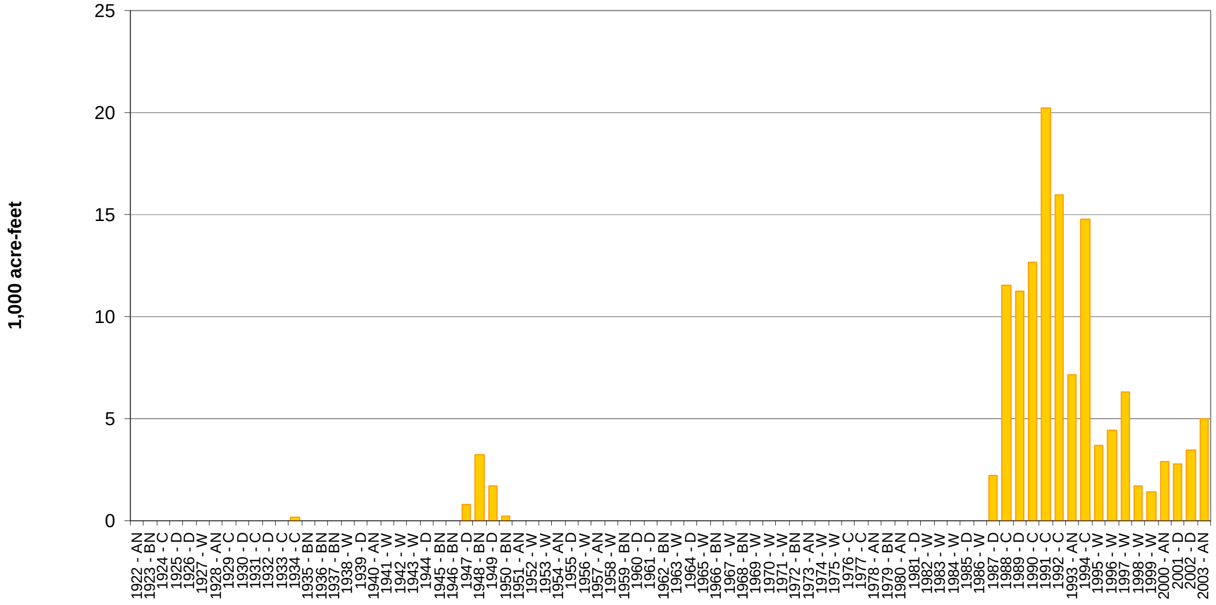


FIGURE 11-60
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 4 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

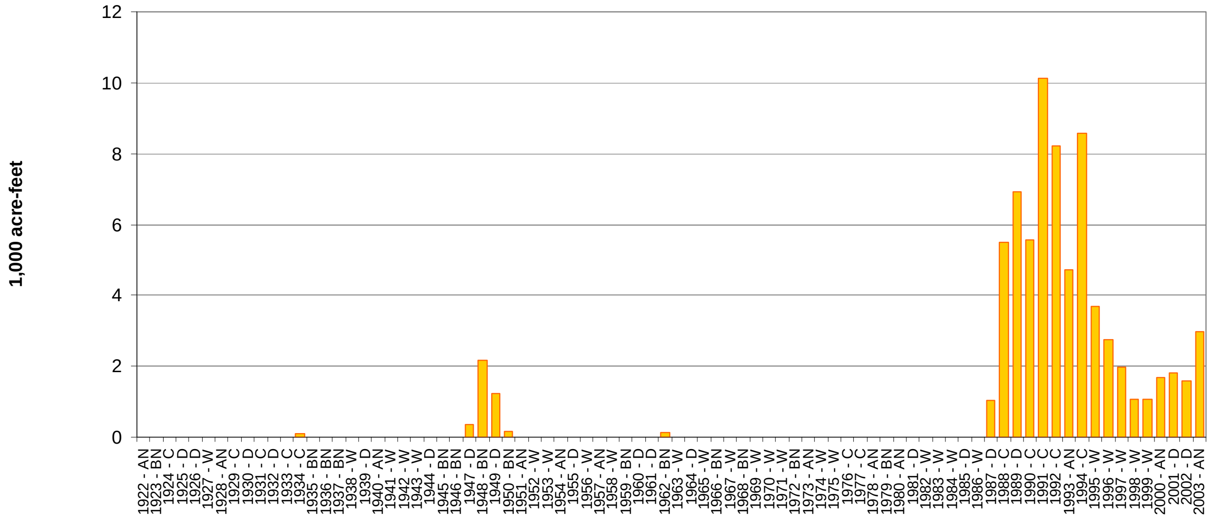


FIGURE 11-61
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 4 - EXISTING WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figures 11-60 and 11-61 indicate that the pattern and volume of additional reservoir release for Scenario 4 is similar to that for Scenarios 1 and 3 with the maximum annual release approximately between those two scenarios.

11.4.3 New Well Field

Results of simulation of pumping from a new well field under Scenario 4 are summarized on Figures 11-62 through 11-64. Peak drawdown in groundwater levels associated with implementation of this alternative is presented on Figure 11-62. This figure depicts simulated drawdown in the pumped aquifer during November 1990. Maximum pumping rates under this alternative occur during 1990, and the drawdown distribution at the end of November represents approximately the maximum drawdown that will occur under this alternative. It can be seen from the figure that the greatest drawdown occurs in the western GCID area at a magnitude of up to 50 feet.

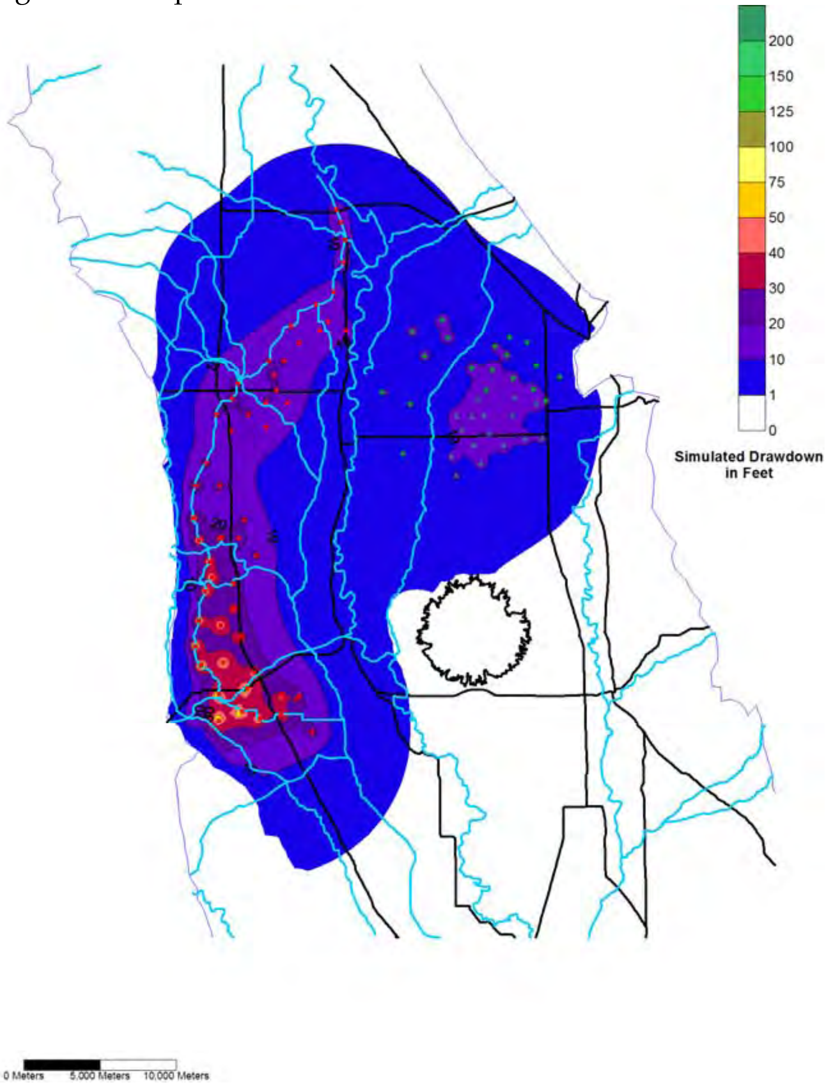


FIGURE 11-62
SIMULATED DRAWDOWN IN THE DEEP AQUIFER IN NOV 1990, SCENARIO 4 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Simulated impacts to surface streams for Scenario 4 with a new well field are summarized on Figures 11-63 and 11-64. These figures show that the greatest impact to surface streams will occur to the Sacramento River, between GCID and Wilkins Slough, and Butte Creek, with smaller impacts estimated to occur to surrounding streams. Figure 11-63 shows that peak cumulative impact to all surface water flows will be a reduction of approximately 65 cfs in December 1990, while a flow reduction of just more than 33 cfs is forecasted to occur on the Sacramento River and a flow reduction of about 15 cfs is predicted on Butte Creek. Peak impact to the Sacramento River will also occur in December 1990 while peak impacts on Butte Creek occur in December 1995. Peak impacts to stream flows on smaller tributary streams peak at less than about 9 cfs, as shown on Figure 11-64.

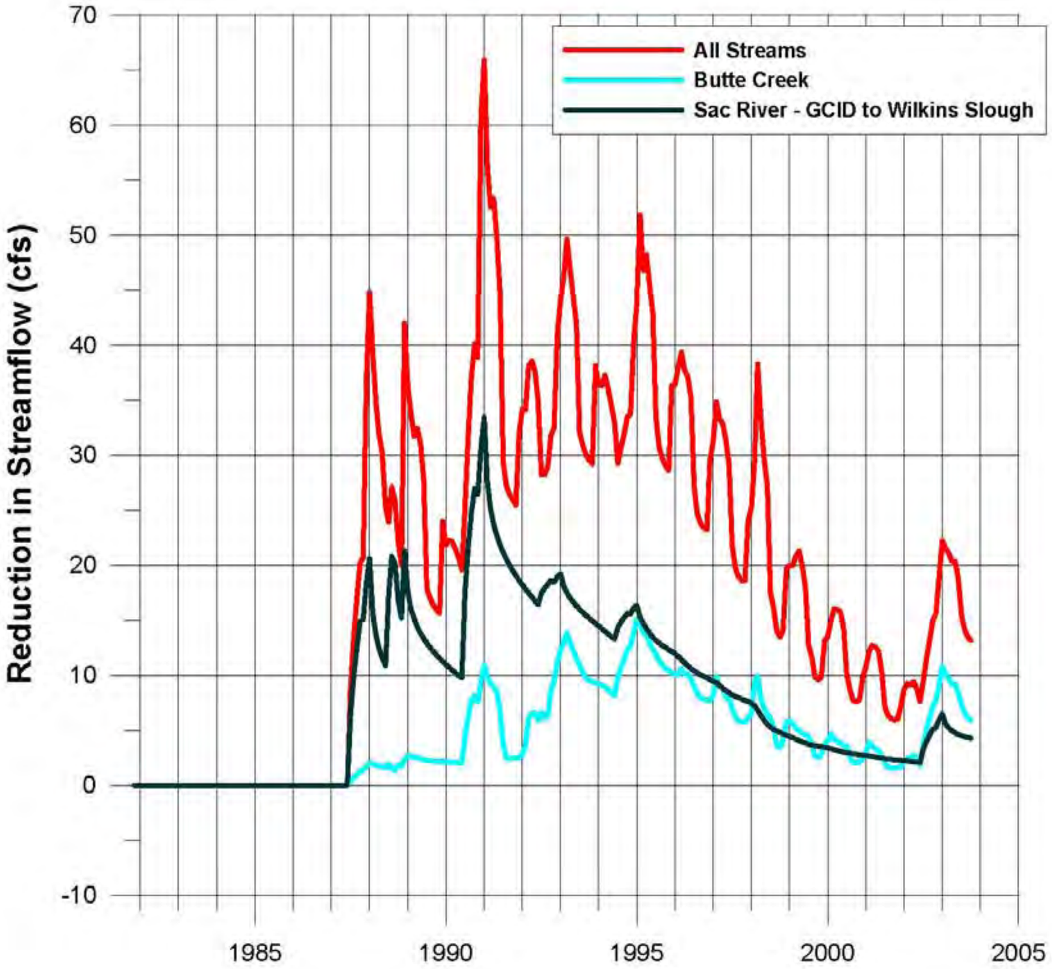


FIGURE 11-63
SIMULATED REDUCTION IN STREAMFLOW TO MAJOR STREAMS, SCENARIO 4 -NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

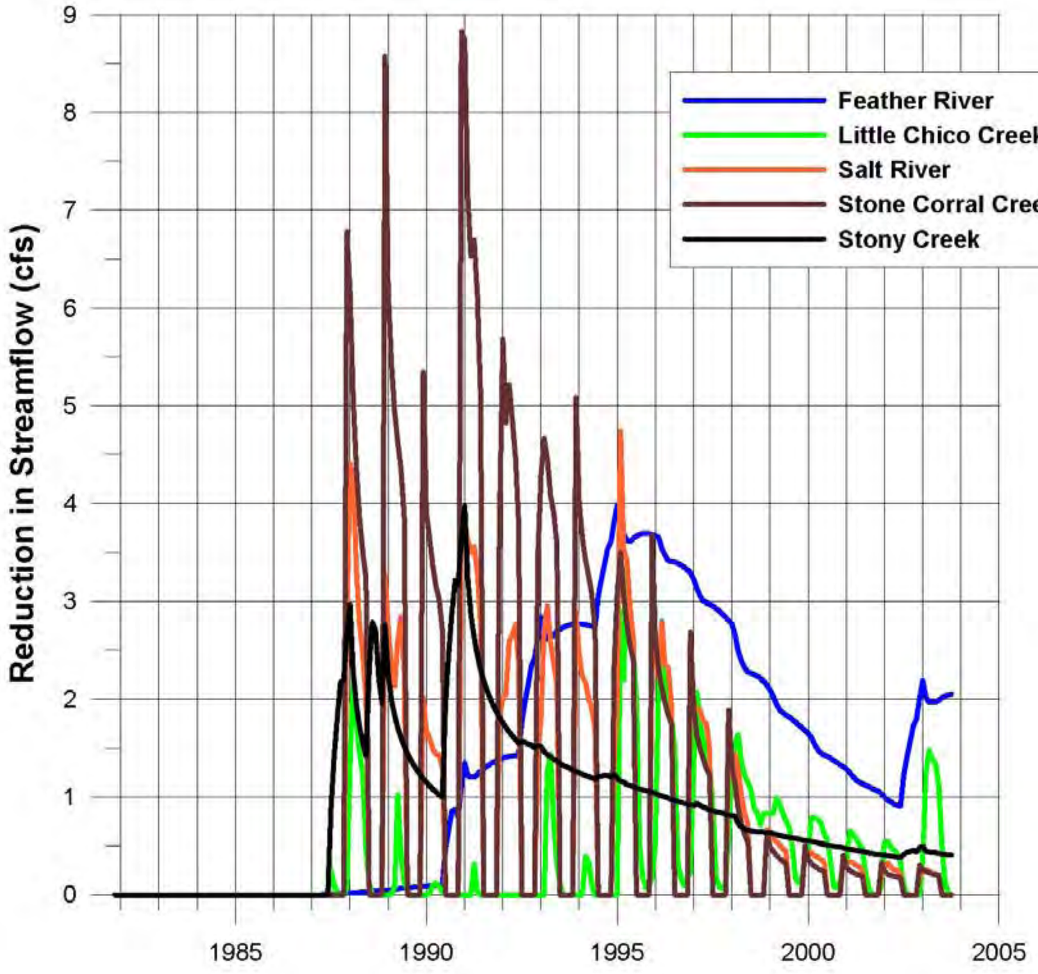


FIGURE 11-64
SIMULATED REDUCTION IN STREAMFLOW TO MINOR STREAMS, SCENARIO 4 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

11.4.4 Reservoir Release for Recharge

Streamflow reductions, due to either increased stream loss to aquifers or decreased aquifer flow into streams, may result in changes in upstream reservoir operations. Time series of simulated streamflow reductions from the groundwater model were input back into the surface water model to determine system conditions at times when reductions occur. Depending on location and timing of reductions, upstream reservoirs may be required to make additional releases to compensate for streamflow reductions due to groundwater pumping. System conditions, either balanced or surplus, were determined from the CalSim II simulation of CVP/SWP operations. Additional releases from Shasta and Oroville were simulated and tracked in the surface water model. Figures 11-65 and 11-66 present annual additional releases from Shasta and Oroville, respectively, for Scenario 4 pumping from a new well field.

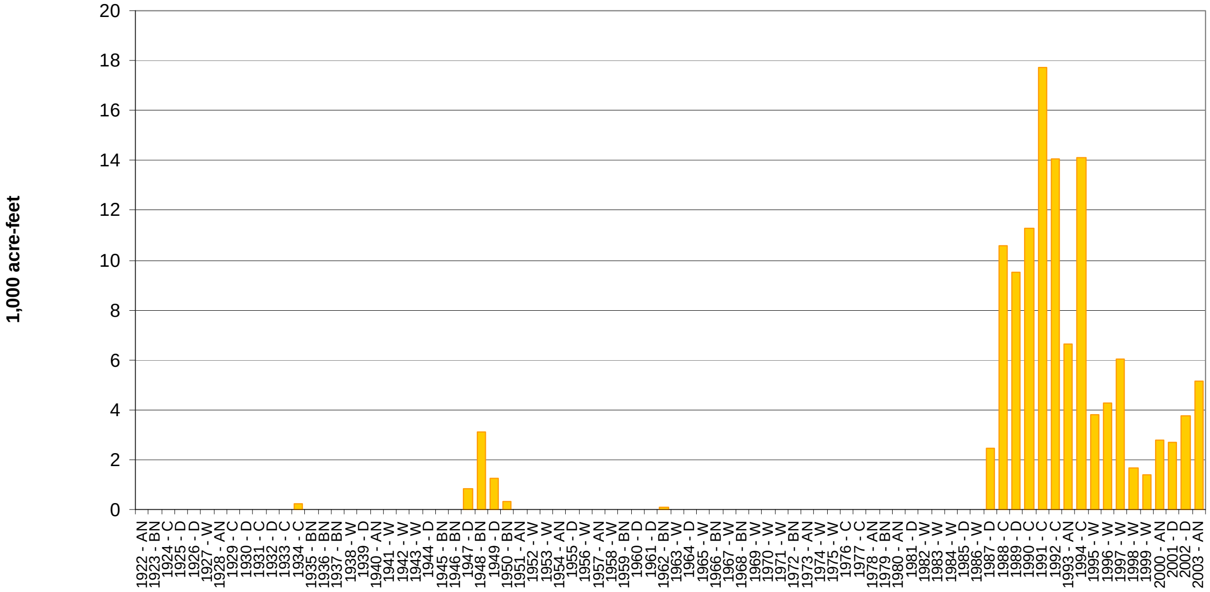


FIGURE 11-65
ANNUAL ADDITIONAL RELEASE FROM SHASTA RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 4 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

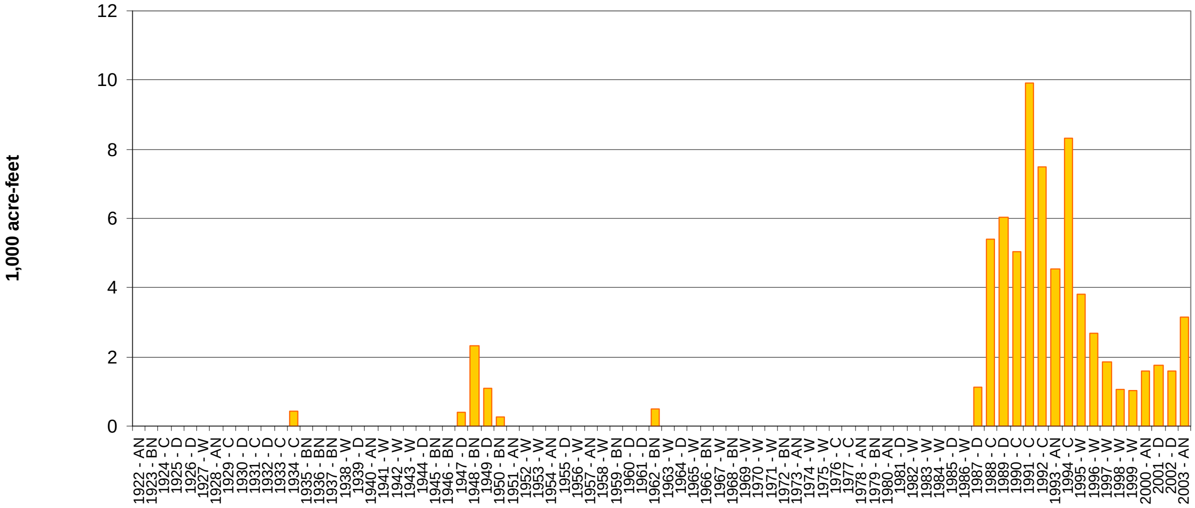


FIGURE 11-66
ANNUAL ADDITIONAL RELEASE FROM OROVILLE RESERVOIR TO COMPENSATE FOR CHANGE IN STREAM-AQUIFER INTERACTION, SCENARIO 4 - NEW WELL FIELD
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

SECTION 12

Sensitivity Analysis and Tradeoffs

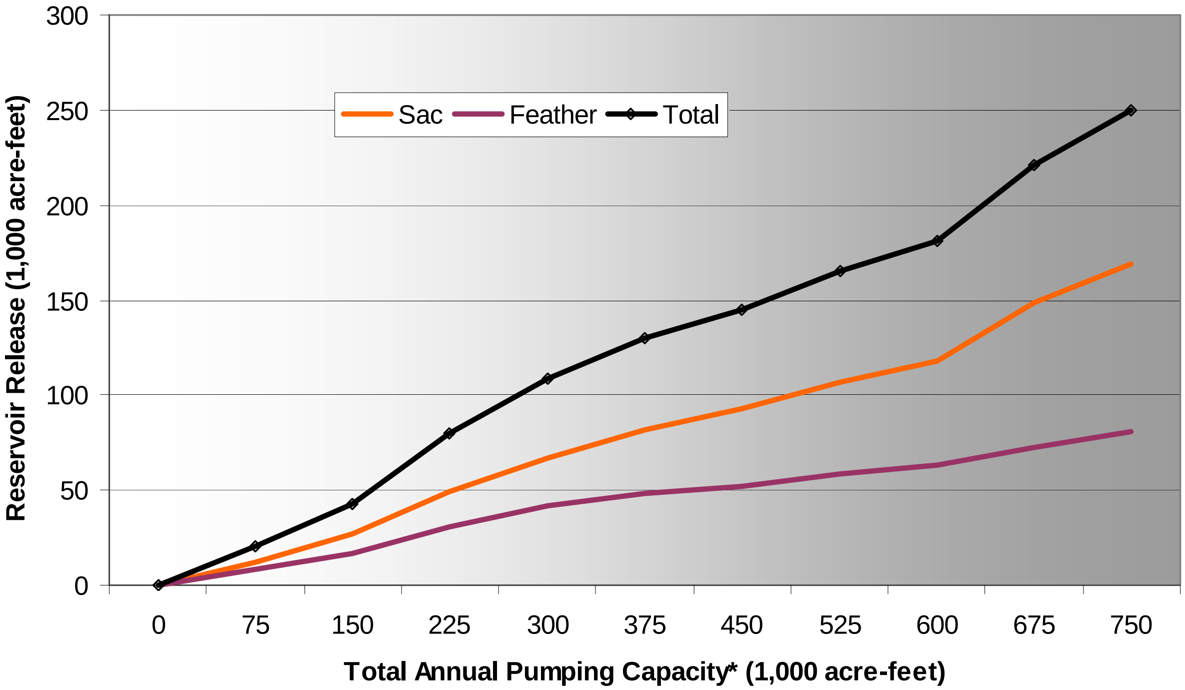
Simulation results presented in the previous section represent specific project sites and operations developed during the course of the analysis. Additional understanding of tradeoffs between certain key parameters and objectives can be gained from using the model in a sensitivity analysis mode in which or a limited number of parameters are varied while holding all other assumptions constant. This section presents results and conclusions for a limited set of model runs focused on better understanding key project inputs and assumptions.

Sensitivity analysis was conducted for several purposes. Sensitivity to parameters, such as project pumping capacity, was evaluated to assist in sizing potential projects. A range of environmental objectives were evaluated because considerable uncertainty exists in the development of objectives, and evaluating a range of possible objectives can help determine how much more or less conjunctive management could contribute to higher or lower flow targets. Evaluating various pumping periods and well field configurations was used to understand how aquifers respond to different pumping magnitudes and durations and the effects on stream-aquifer interactions.

12.1 Pumping Capacity

The surface water model was used to simulate a wide range of project pumping capacities and determine project benefits. Results of these simulations were one factor considered in determining final project capacities. The surface water model was used to simulate a range of pumping capacities to determine if certain capacities provided higher levels of project benefits. Project benefits were summarized as average annual reservoir release for both agricultural and environmental objectives.

Figure 12-1 illustrates that project benefits increase at different rates for different ranges of pumping capacities. For example, the incremental benefit of an additional 75 TAF of pumping capacity is greater when increasing pumping capacity from 150 to 225 TAF of total capacity than it is when increasing from 75 to 150 TAF, as illustrated by the steeper slope in the line. Benefits of incremental increases are smaller from 300 to 600 TAF (less steep line) and then increase again above 600 TAF. However, Figure 12-1, is shaded at the higher pumping capacities because projects of this size are not feasible and are not proposed for this project.

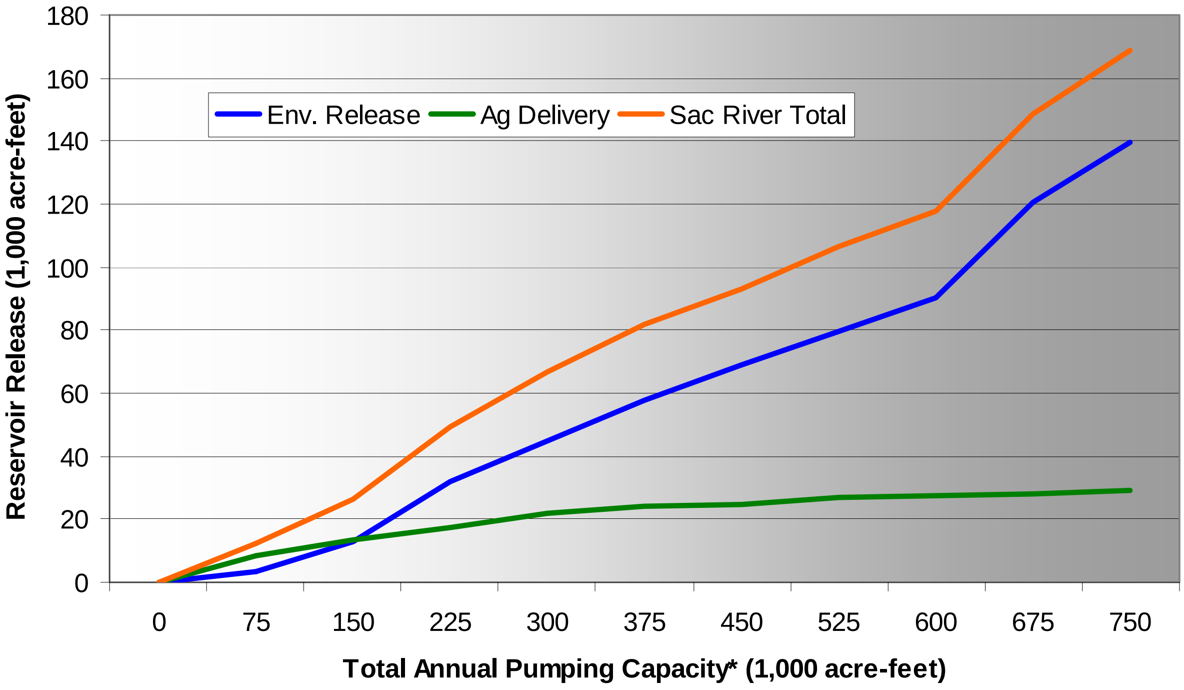


**Pumping capacity split 2:1 between GCID and Butte Basin*

FIGURE 12-1
TOTAL PROJECT BENEFITS FOR A RANGE OF PUMPING CAPACITIES
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figure 12-1 illustrates that projects between 75 and 150 TAF of pumping capacity have approximately the same marginal benefits when adding additional capacity. Figure 12-1 also illustrates that projects with 300 TAF may provide a good tradeoff at the upper end of the curve between pumping capacity and project benefits and that marginal benefits of increasing pumping capacity above 300 TAF are smaller than those realized by increasing from 150 to 300 TAF.

Project benefits presented on Figure 12-1 were compiled from reservoir releases to meet agricultural and environmental objectives. The model was set to first meet environmental objectives because of the all-or-nothing nature of those objectives. Figures 12-2 and 12-3 show the tradeoff between meeting agricultural and environmental objectives that occurs across a range of project pumping capacities.

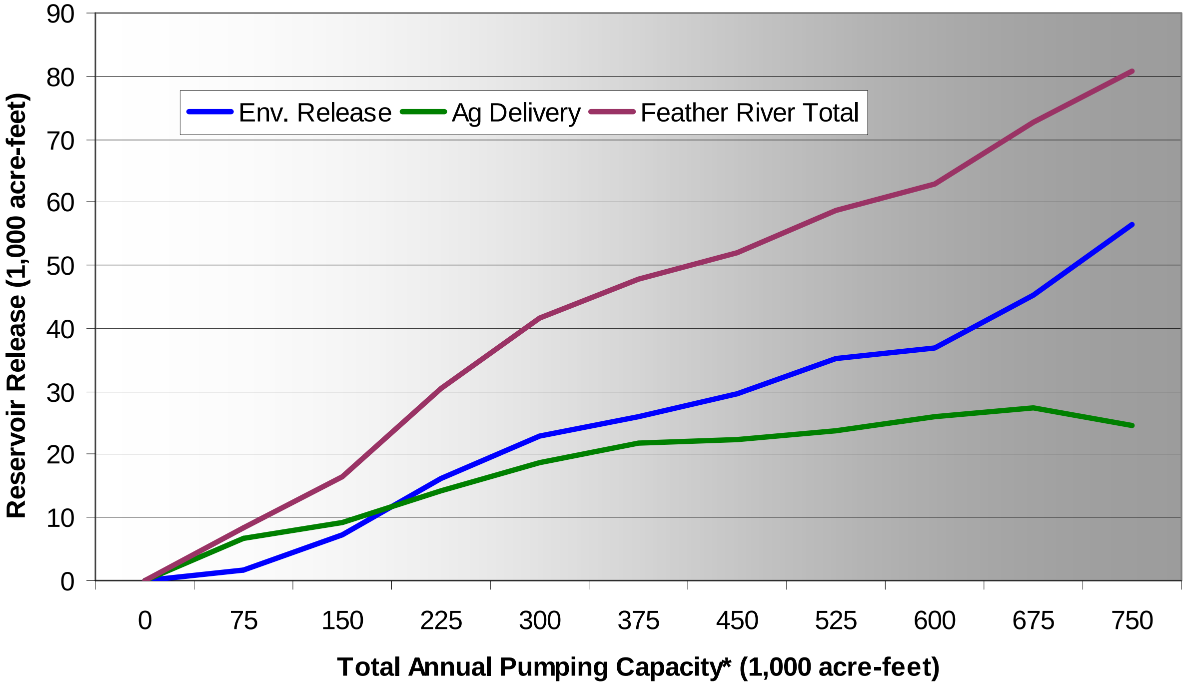


**Pumping capacity split 2:1 between GCID and Butte Basin*

FIGURE 12-2
SACRAMENTO RIVER AGRICULTURAL AND ENVIRONMENTAL PROJECT BENEFITS FOR A RANGE OF PUMPING CAPACITIES
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 12-2 provides additional detail on the split between project benefits for agricultural demand and environmental objectives on the Sacramento River. Projects with smaller pumping capacities do not provide as much water supply for environmental objectives. This occurs because water costs for meeting environmental objectives typically exceeds project assets for lower pumping capacity projects. The result is smaller pumping capacity projects supply a greater portion of total benefits to agricultural demands because agricultural objectives are not constrained by a minimum threshold. As pumping capacity, and therefore available project assets increase, a greater portion of total benefits are directed toward meeting environmental objectives. However, this does not necessarily come at the sake of meeting additional agricultural demand. A project with 300 TAF of pumping capacity is providing an average annual agricultural supply increase of approximately 20 TAF, and pumping capacity would need to be significantly increased to provide additional agricultural water supply, up to a maximum of approximately 30 TAF per year. Maximum agricultural benefit is also constrained by the restriction on project operations during Shasta critical years. In these years, there is significant unmet agricultural demand that conjunctive management projects cannot satisfy under assumptions made for this analysis.

Figure 12-3 shows same relationships between pumping capacity and agricultural, and environmental benefits presented for the Sacramento River on Figure 12-2 also exist on the Feather River.

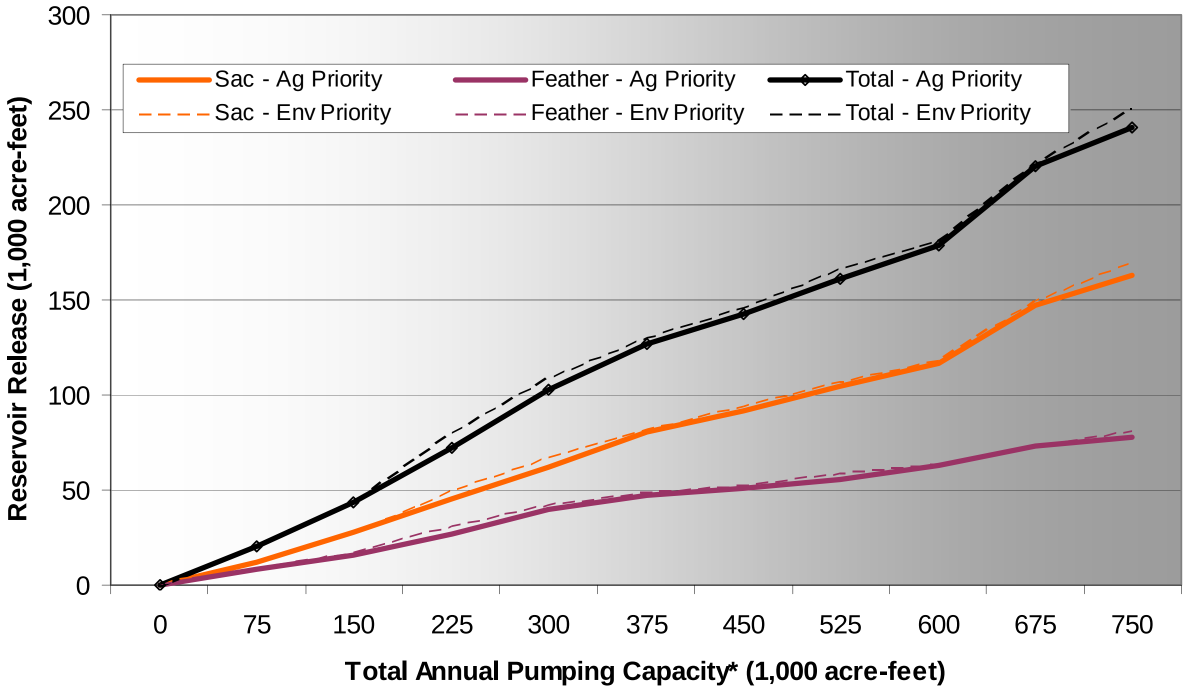


**Pumping capacity split 2:1 between GCID and Butte Basin*

FIGURE 12-3
FEATHER RIVER AGRICULTURAL AND ENVIRONMENTAL PROJECT BENEFITS FOR A RANGE OF PUMPING CAPACITIES
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

12.2 Prioritization of Objectives

The ability to direct additional water supply from conjunctive management toward meeting agricultural objectives first and environmental objectives second was also simulated. When environmental objectives are first priority, agricultural objectives are met more frequently for smaller capacity projects while environmental objectives are met more frequently for larger capacity projects. Figure 12-4 presents the same results as seen on Figure 12-1, with additional results that reflect when agricultural objectives are given first priority.



**Pumping capacity split 2:1 between GCID and Butte Basin*

FIGURE 12-4
TOTAL PROJECT BENEFITS FOR A RANGE OF PUMPING CAPACITIES WITH HIGHER PRIORITY TO AGRICULTURAL OBJECTIVES (AG PRIORITY) AND HIGHER PRIORITY TO ENVIRONMENTAL OBJECTIVES (ENV PRIORITY)
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 12-4 illustrates model results are insensitive to prioritization of objectives for lower pumping capacity projects. However, as pumping capacity increases and conjunctive management projects are able to meet additional environmental objectives, total project benefits decrease when meeting agricultural objectives first. Table 12-1 compares average annual benefits for each objective on each river system with different priorities and the number of environmental objectives met by conjunctive management projects.

TABLE 12-1
Comparison of Average Annual Benefits for 300 TAF Pumping Capacity Project with Different Prioritization of Objectives
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Sacramento River			**Feather River**		
	Env. First	**Ag First**	**Change**	**Env. First**	**Ag First**	**Change**
Ag Benefit (TAF)	22	26	+4	20	23	+3
Env Benefit (TAF)	45	36	-9	23	18	-5
Env Obj. Met (#)	57	50	-7	54	40	-14

Table 12-1 shows when prioritizing agricultural objectives first average annual agricultural benefits increase, but not by the same volume environmental benefits decrease. Therefore there is a reduction in the total project benefits when prioritizing agricultural benefits first, as illustrated on Figure 12-4.

12.3 Reservoir Drawdown Targets

A reservoir storage matrix is used in combination with project groundwater pumping capacity to determine project assets available to meet objectives each year. Results previously presented for Scenarios 1 through 4 assume a minimum end-of-September storage of 2,400 TAF for Shasta Reservoir and 1,500 TAF for Oroville Reservoir. Model sensitivity to these assumptions was evaluated to better understand risk to water supplies and cold water pool management in subsequent years.

Figure 12-5 illustrates effects of changes in minimum fall storage levels on end of September storage. A line at 1,900 TAF is shown because this is the minimum level specified in the biological opinion for winter run Chinook salmon and changes in storage below this level can have significant impacts on Reclamation's ability to manage cold water pool and meet existing temperature control criteria. Setting minimum fall storage levels less than 2,400 TAF can impact storage in subsequent years when storage goes below 1,900 TAF. Setting minimum storage levels above 2,400 TAF reduces project benefits.

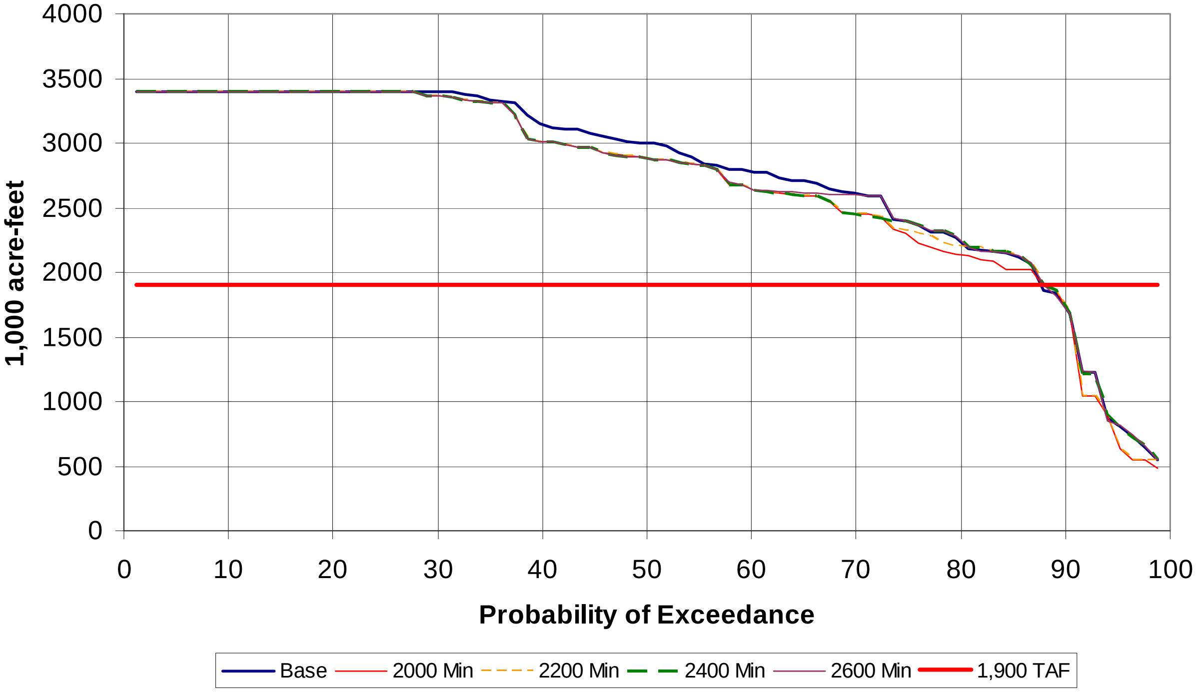


FIGURE 12-5
EXCEEDANCE PROBABILITY FOR END OF SEPTEMBER SHASTA STORAGE WITH SELECT MINIMUM STORAGE REQUIREMENTS
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 12-6 illustrates similar results for Oroville Reservoir. There is no specified target for fall storage in Oroville, but it is understood that hydropower operations are affected when storage goes below 1,000 TAF. Results are less clear because of the smaller differences between base and project conditions; however, more aggressive operation of Oroville with a lower fall storage level may put operations in future years at risk. Therefore, 1,500 TAF was selected as a balance between achieving conjunctive management project benefits and operational risks.

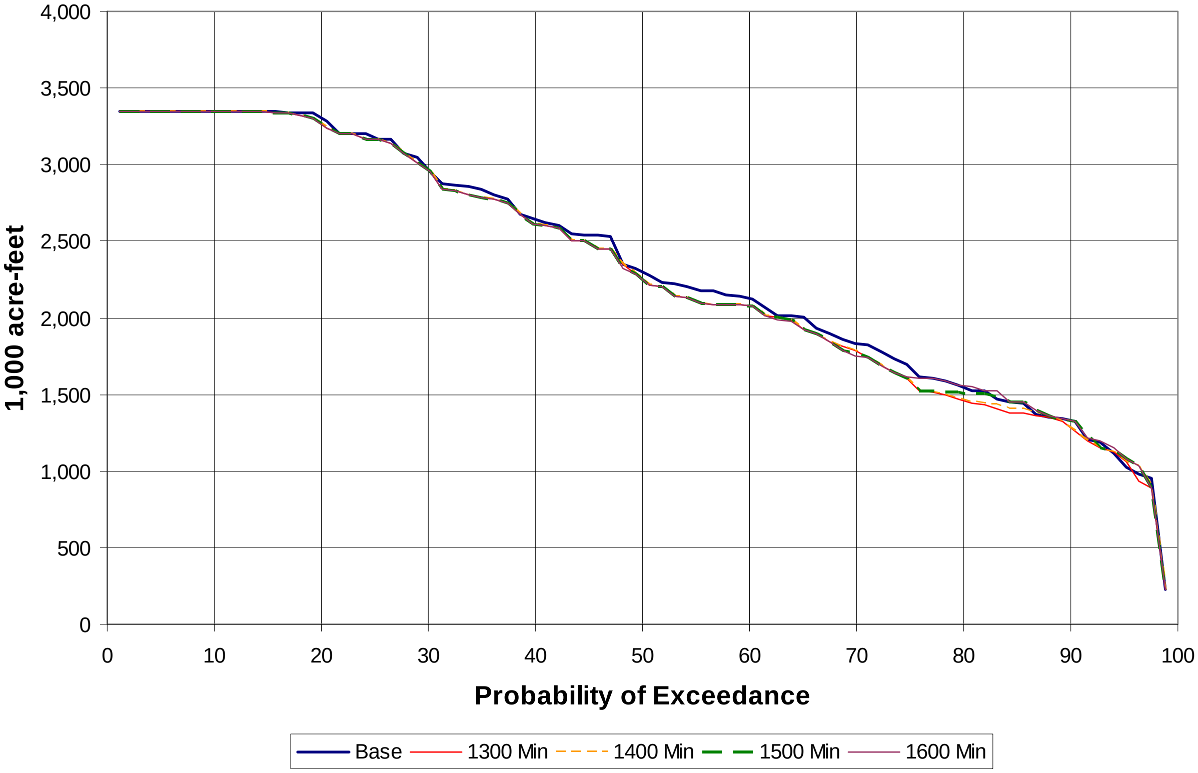


FIGURE 12-6
EXCEEDANCE PROBABILITY FOR SEPTEMBER OROVILLE STORAGE WITH SELECT MINIMUM STORAGE REQUIREMENTS
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

12.4 Environmental Objectives

Considerable uncertainty surrounds developing of environmental objectives; therefore, limited sensitivity analysis was performed to determine if changes in environmental objectives resulted in significant changes in project benefits. For example, if a 10 percent increase in flow targets specified for each objective resulted in no objectives being satisfied for a given scenario, the results from this scenario would be interpreted to contain significant uncertainty. Likewise, if project benefits are consistent across a range of environmental objectives, conjunctive management projects are likely to provide a level of environmental benefit, even if flow targets are slightly different than those simulated.

Figures 12-7 through 12-10 present simulation results of varying environmental targets (presented in Tables 9-1 through 9-5, by more or less than 10 percent. Figures 12-7 through 12-10 show the years that objectives are met, either in the base condition or through project release, and total number of years met. Results are aggregated for both river systems.

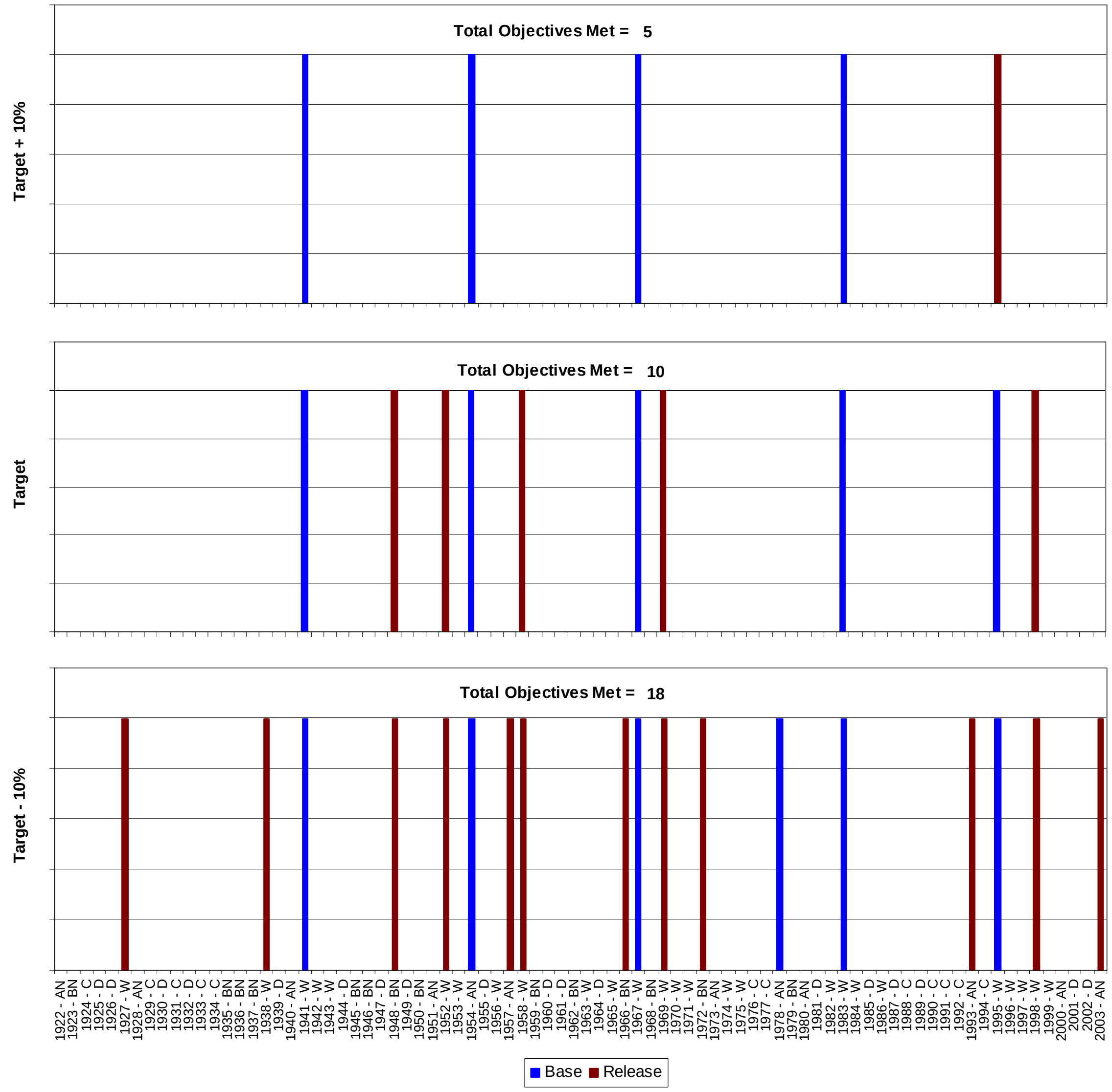


FIGURE 12-7
SENSITIVITY RESULTS FOR SPRING PULSE OBJECTIVE
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 12-7 shows that the larger water costs associated with meeting a larger spring pulse flow may decrease the ability of conjunctive management projects to satisfy the objective. Decreasing the flow target will increase the frequency of meeting the objective. The ability of conjunctive management projects to meet the spring pulse objective is sensitive to changes of more or less than 10 percent in the objective. Additionally, changes in the flow objective also change the frequency of meeting the objective with base operations.

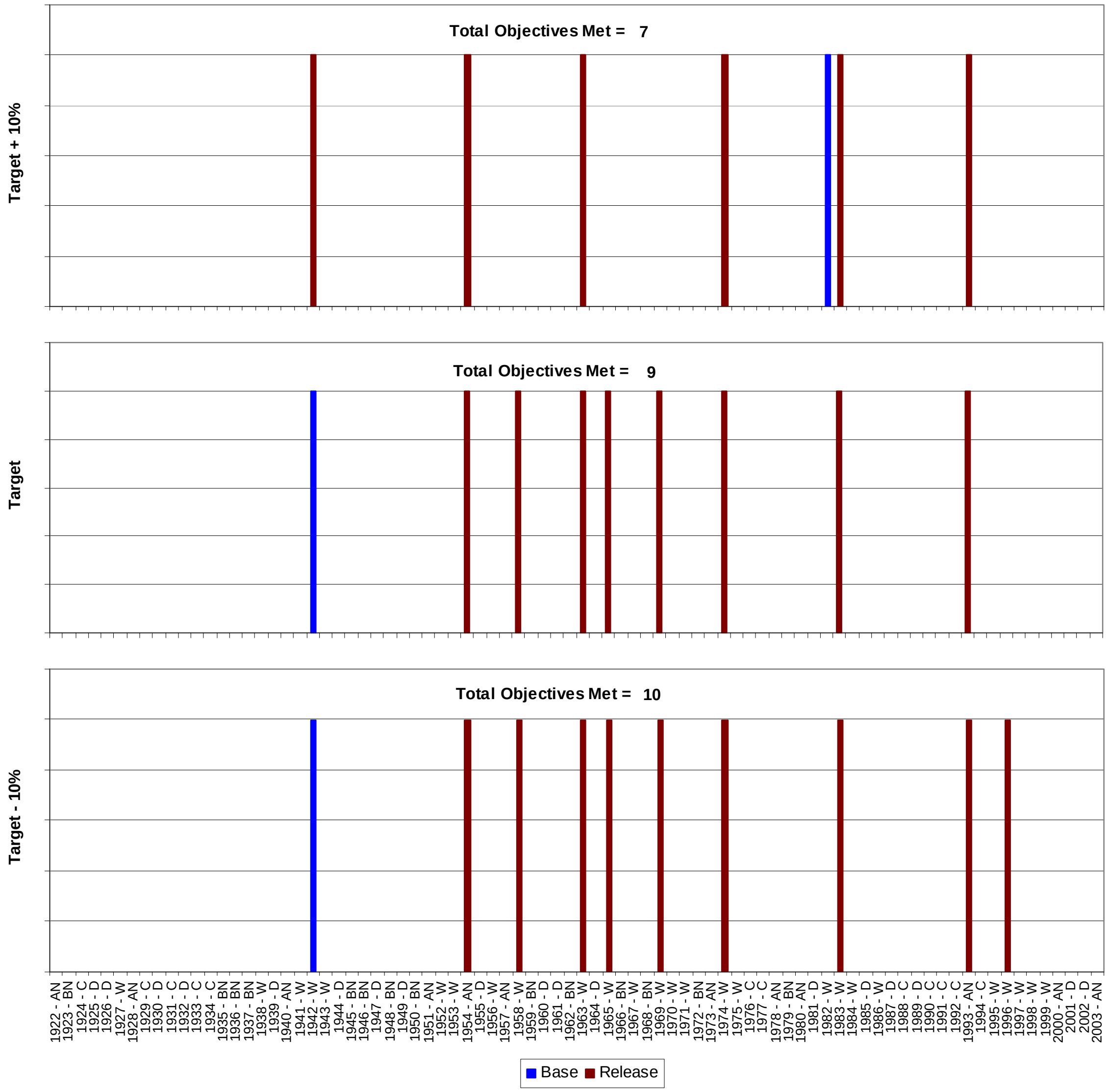


FIGURE 12-8
SENSITIVITY RESULTS FOR RIPARIAN RECRUITMENT OBJECTIVE
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION
MODELING REPORT

Figure 12-8 shows that riparian recruitment is less sensitive to changes in targets than the spring pulse objective. Changes in flow targets do not result in significant changes in the frequency of satisfying the objective.

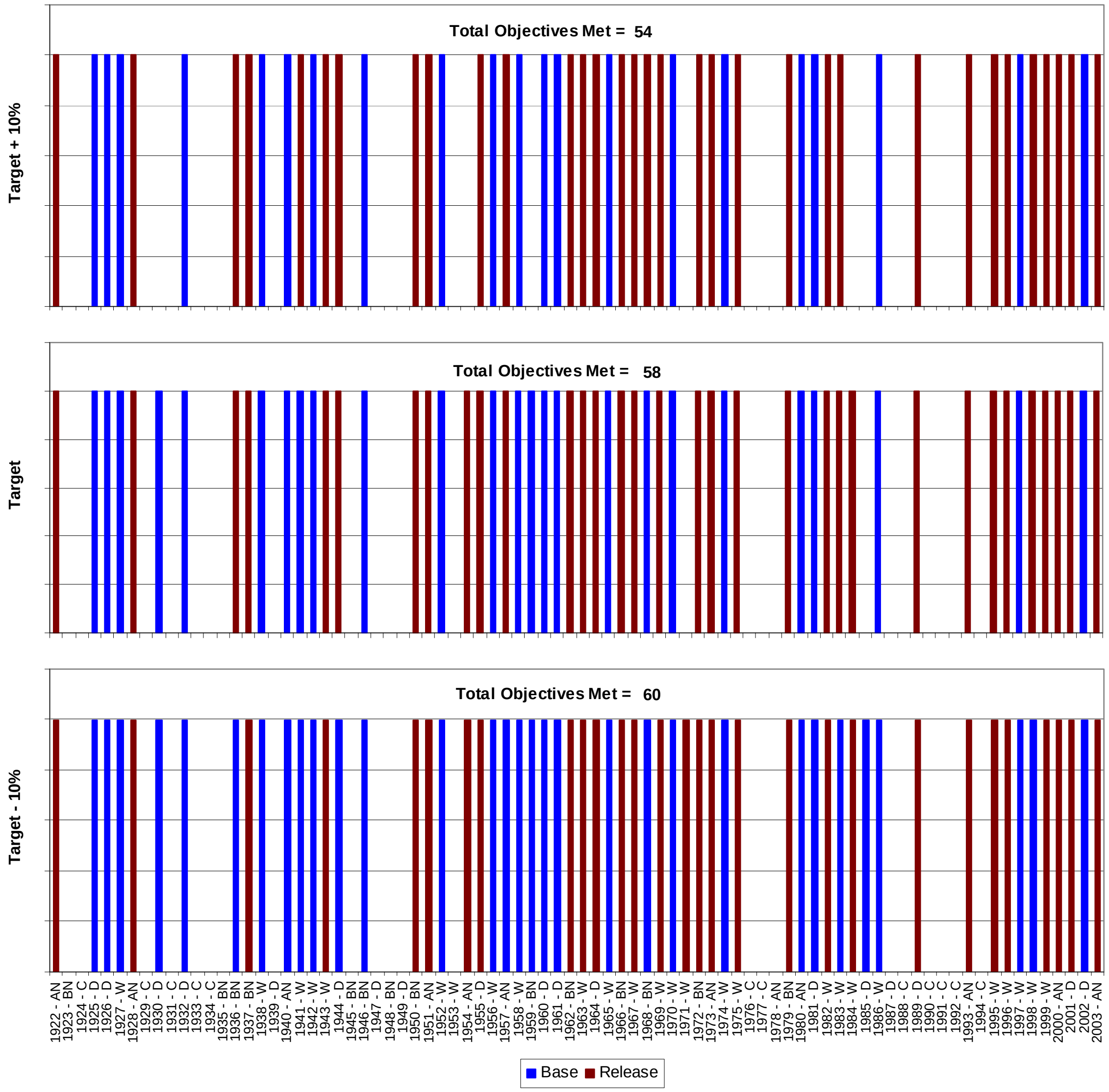


FIGURE 12-9
SENSITIVITY RESULTS FOR GEOMORPHIC OBJECTIVE
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 12-9 illustrates that the geomorphic objective is less sensitive to changes in targets than the spring pulse objective. Lower water cost of meeting a short duration objective results in being able to meet the objective, even when it is increased by 10 percent. Additionally, the objective is satisfied so frequently that reducing the flow target does not result in the objective being satisfied much more often.

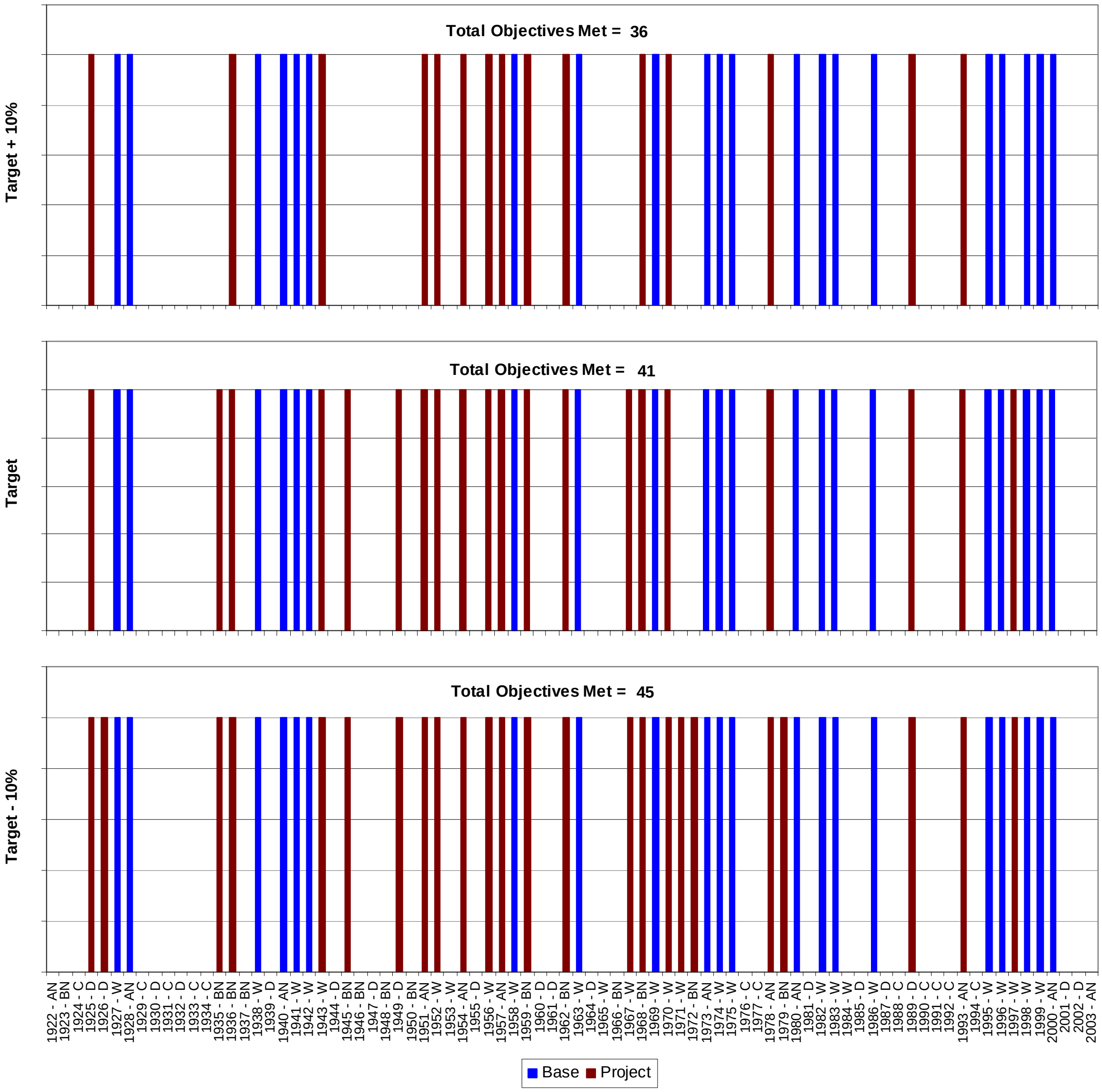


FIGURE 12-10
SENSITIVITY RESULTS FOR FLOOD PLAIN INUNDATION OBJECTIVE
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 12-10 illustrates that the flood plain inundation objective is also less sensitive to changes in the target than the spring pulse objective. Therefore, the conjunctive management project, including some form of weir modification, to allow inundation at lower river stages will allow the objective to be satisfied approximately 40 times if the flow target is within 10 percent of the target simulated in Scenarios 1 through 4.

SECTION 13

Systemwide Effects

This project focused operation of conjunctive management projects within the Sacramento Valley on developing water supply for uses within the Sacramento Valley. Developed water supply was split between environmental and agricultural objectives. However, water released to meet environmental objectives within the Sacramento Valley continues into the Sacramento-San Joaquin River Delta, where it may have additional environmental benefits or potentially be exported for delivery to CVP and SWP contractors south of the Delta.

13.1 Delta Salinity

Changes in Delta inflow, either increases from environmental releases or decreases when reservoirs or groundwater refill with surplus surface water, have the potential to change salinity conditions in the Delta. Formal simulation and analysis of expected changes is beyond the scope of modeling conducted to date. Generally, environmental releases will increase Delta inflow and improve salinity conditions, depending on how export operations respond to increased inflow. To the extent that environmental objectives can be met during drier periods those releases have potential to improve Delta salinity. Operations during wetter periods that either increased or decreased inflow may not result in large changes in Delta salinity. Overall, conjunctive management projects as described for this project will decrease average annual Delta inflow by the consumptive use of additional agricultural deliveries made possible by the project. Figures 13-1 and 13-2 present annual changes in inflow for Scenarios 1 and 2, respectively. Changes from Scenarios 3 and 4 are expected to be similar to those shown for Scenario 1.

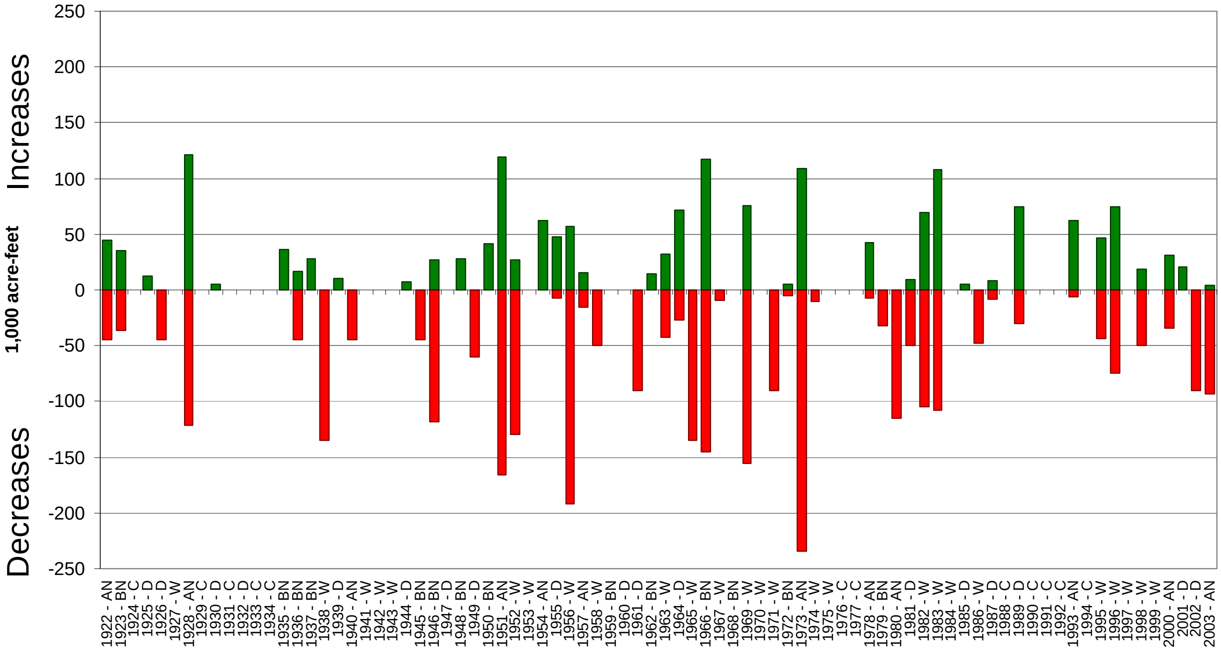


FIGURE 13-1
CHANGE IN ANNUAL DELTA INFLOW, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

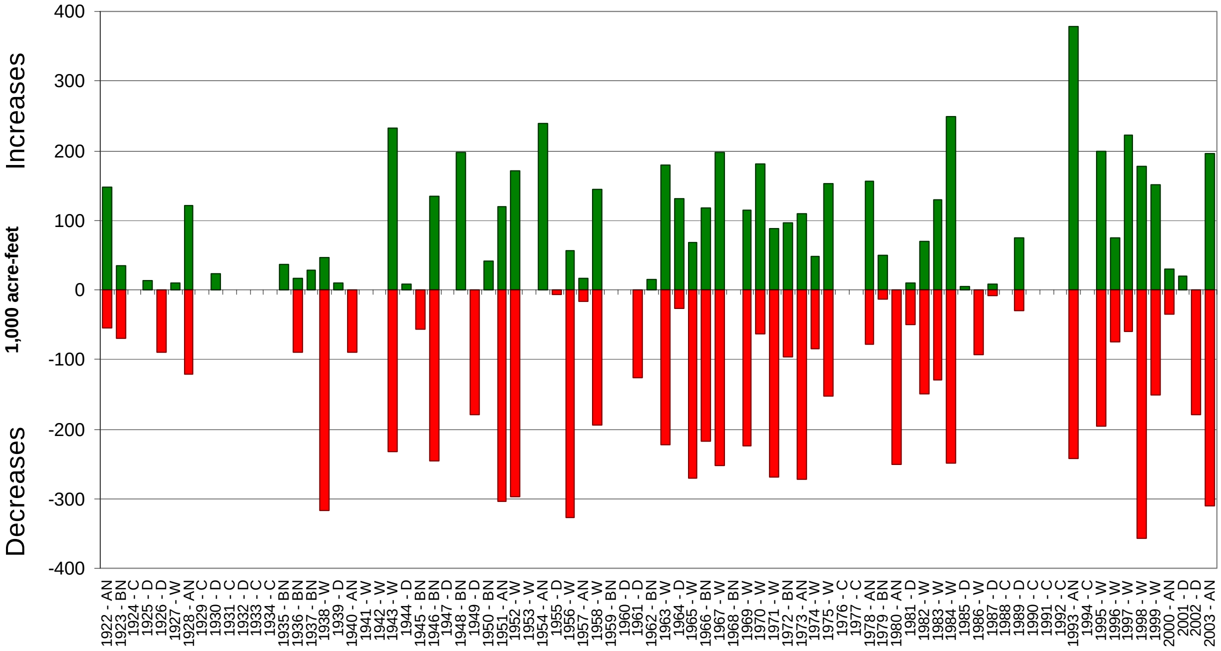


FIGURE 13-2
CHANGE IN ANNUAL DELTA INFLOW, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

13.2 South of Delta Water Supply

A preliminary analysis of the ability to export simulated environmental releases was made using the underlying CalSim II operations. This analysis considers the constraints imposed by D-1641 Delta flow and salinity standards, CVPIA b(2) restrictions, the Vernalis Adaptive Management Plan (2000), and export pumping capacity constraints. Analysis did not include pumping restrictions for protecting Delta smelt as proposed in the recent OCAP Biological Opinion (U.S. Fish and Wildlife Service, 2008). Export restrictions for protection of Delta smelt may significantly reduce ability to export environmental releases because smelt restrictions limit export operations during winter and spring months when environmental releases are made. Additionally, it was assumed that there is demand for any additional water that could be exported.

Figures 13-3 and 13-4 illustrate annual time series of total potential export of environmental releases made from Shasta and Oroville for Scenarios 1 and 2. Results for Scenarios 3 and 4 are essentially the same as for Scenario 1, because the timing and volume of environmental release does not change.

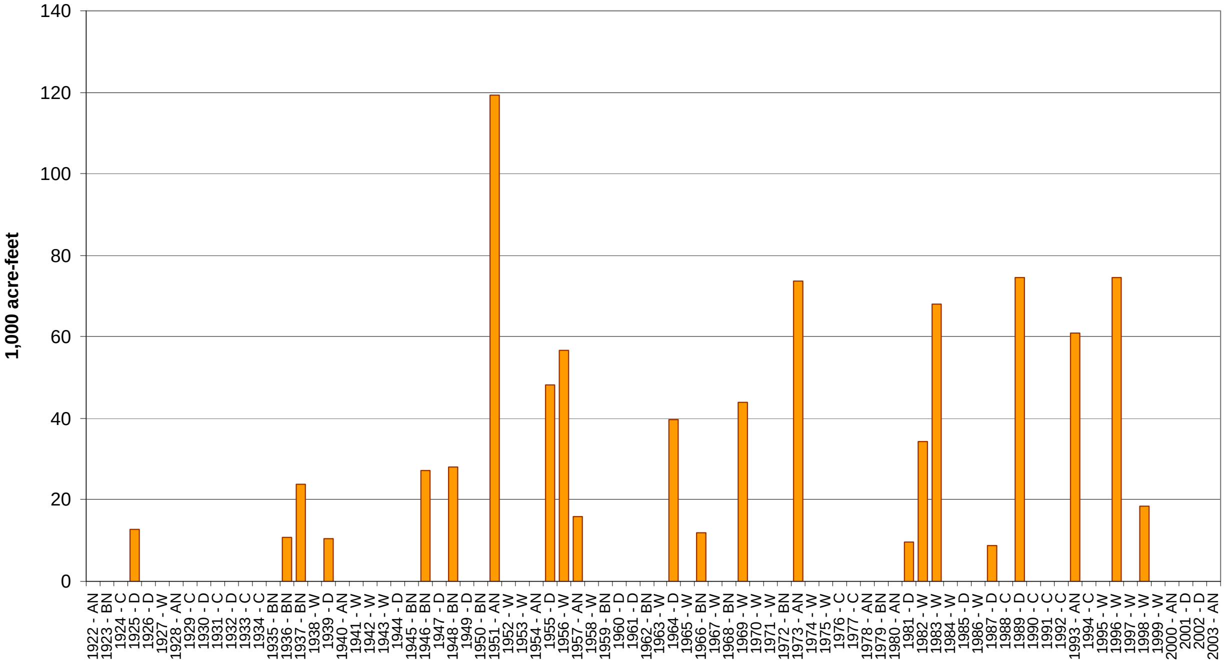


FIGURE 13-3
POTENTIAL EXPORT OF ENVIRONMENTAL RELEASES, SCENARIO 1
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 13-3 illustrates the volume and timing of additional export that may occur with conjunctive management projects. Average annual exports increase by approximately 11 of the 22 TAF from environmental releases on the Sacramento and Feather Rivers. The majority of additional exports occur when CVP and/or SWP San Luis Reservoir storage is full and would therefore provide additional Section 215 water for CVP contractors and Article 21 water for SWP contractors.

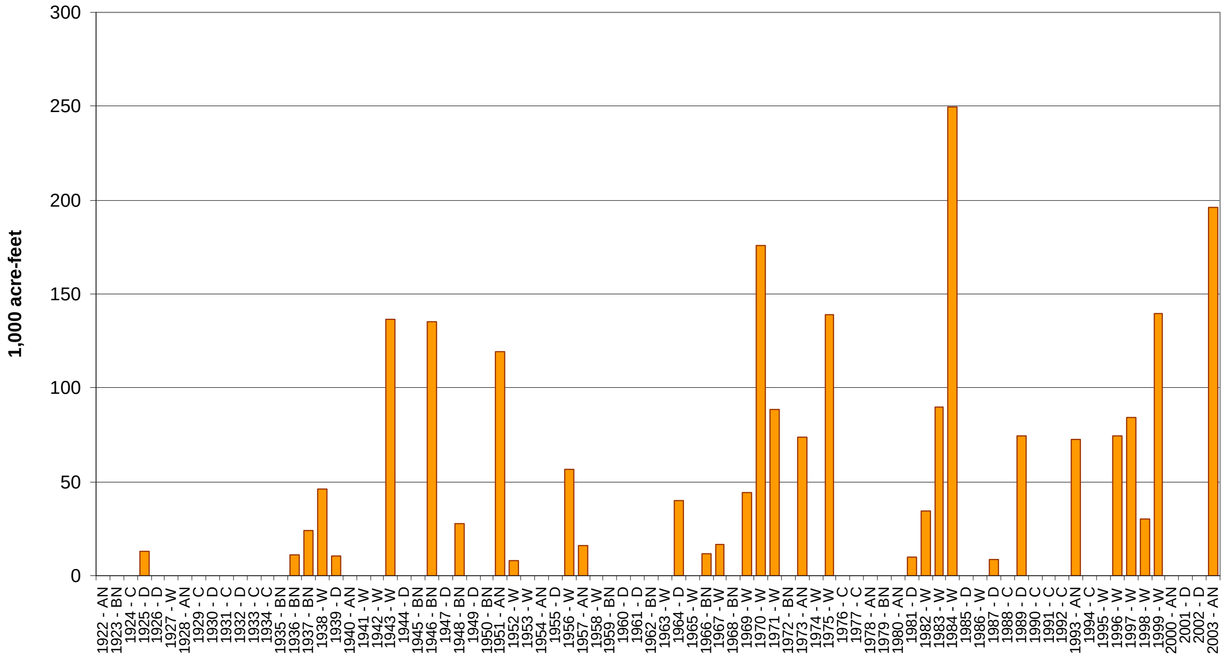


FIGURE 13-4
POTENTIAL EXPORT OF ENVIRONMENTAL RELEASES, SCENARIO 2
SACRAMENTO VALLEY CONJUNCTIVE WATER MANAGEMENT TECHNICAL INVESTIGATION MODELING REPORT

Figure 13-4 presents the same results for Scenario 2 with an average annual export of 28 of the 68 TAF of environmental releases. Exports with Scenario 2 may increase by up to 250 TAF in a given year. In these years with large increases, exports and may be limited by the ability to use or store the water south of the Delta.

13.3 Other Changes

Analysis conducted to date focused on operations on the main stem of the Sacramento and Feather Rivers, and CVP and SWP reservoirs on those rivers. In reality, the water system in California is operated as a whole and changes in one area, particularly large components of the system, such as Shasta and Oroville Reservoirs, will ripple into other areas. While not addressed in this report, it is understood that these changes would require additional analyses at a feasibility level.

SECTION 14

Model Limitations and Areas for Refinement

14.1 Groundwater Model

While SACFEM is a powerful tool designed specifically to evaluate effects of conjunctive water management pumping on surface water and groundwater resources, several areas for refinement remain. Due to constraints on available resources for this project, it was not possible to perform a rigorous transient calibration of the model to observed historic water level hydrographs across the valley. This effort would help improve the level of confidence that the model is accurately simulating transient patterns in groundwater levels seen historically. However, a preliminary assessment of the accuracy of SACFEM at matching a limited number of historic hydrographs was performed, and the model appears to generally replicate historically observed water levels quite well over the 22-year period of simulation (1982 through 2003).

Another area of potential refinement is to further evaluate behavior of smaller unregulated tributaries across the valley, specifically to better understand timing and magnitude of groundwater recharge that occurs from these surface water features. In the current analysis, it was assumed that unregulated streams were dry from June through October. While this assumption is reasonable, it is likely that behavior of these streams is more complex. Further, some of these tributary streams are used as conveyance facilities to deliver water within various water districts. This would result in streams being active over summer months, and potential sources of recharge to the groundwater system. An analysis of these stream characteristics could improve the accuracy of the simulation of recharge sources to the groundwater system, especially over the summer months.

Forecasts provided by modeling tools contain some degree of uncertainty, due to limitations of replicating a complex physical system with a more idealized mathematical representation of that system. Analyses described herein should be considered a planning level analysis that tests the general viability of conjunctive water management strategies presented, and provides a general estimate of benefits that may be realized by implementation of these projects. However, these evaluations will need to be significantly refined, both in specificity of infrastructure and operational protocols and response of the natural system to these operations, before a project of this type could be carried to the design phase.

14.2 Surface Water Model

Surface water modeling and analysis was conducted at a pre-feasibility, planning level and required numerous simplifying assumptions.

14.2.1 Forecast-based Operations

The surface water model uses perfect foresight in operating reservoirs and determining ability to meet environmental objectives. This results in an ideal operation of system reservoirs and decisions to meet project objectives. In reality, project operators must rely on imperfect forecasts of water supply and demands when making daily decisions. In actual operations, there would be instances in which environmental objectives would be met or missed due to changing conditions that cannot be forecasted.

One method to address this uncertainty in future analyses would be to implement forecast-based decision logic that may help to illuminate some of the challenges in implementing environmental objectives in real-world operations. For example, because environmental objectives are specified for spring months, a forecast of the water year type (e.g., wet or above normal) is needed to estimate the flow target. In actual operations these forecasts will be uncertain and operations will need to respond to actual hydrology.

14.2.2 Temperature and Power Analyses

Conjunctive management operations as described and simulated for this report may have impacts on the ability to meet temperature control criteria, and the generation and use of CVP and SWP hydropower. For example, in some years, making releases for environmental objectives in spring may create challenges in meeting temperature control criteria in the fall, depending on how water is released from reservoirs. Additionally, large releases for certain objectives may be constrained by power plant capacities and may occur at times when power is less valuable. A better understanding of these constraints and simulation of resulting effects is necessary in future phases of the project.

14.2.3 System Response

Analysis presented in this report focused on operation of only part of the CVP/SWP system. Shasta and Oroville Reservoirs and the Sacramento and Feather Rivers are part of a larger system that is operated in a coordinated manner. Simulation of only part of the system may underestimate benefits or impacts to other areas of the system. Preliminary analysis of systemwide effects based on how conjunctive management operations change, Delta inflows need to be refined and expanded to other areas of the system.

SECTION 15

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Vernalis Adaptive Management Plan as described and implemented in State Water Resources Control Board Revised Decision 1641, State Water Resources Control Board, March 15, 2000.

Appendix A
CalSim II Common Assumptions

APPENDIX A

CalSim II Common Assumptions

Table A-1 summarizes assumptions used in CalSim II simulation of CVP and SWP reservoirs used in the surface water model at the existing level of development (Existing Conditions Assumption).

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	Future No Action Condition Assumption	Supplemental Future Condition (#1) Assumption
Planning Horizon	2004[a]	2030[a]	Same
Demarcation Date	June 1, 2004[a]	Same	Same
Period of Simulation	82 years (1922 through 2003)	Same	Same
HYDROLOGY			
Level of Development	2005 level[b]	2030 level[c]	Same
Sacramento Valley (excluding American River)			
CVP	Land-use based, limited by contract amounts[d]	Same	Same
SWP (FRSA)	Land-use based, limited by contract amounts[e]	Same	Same
Non-Project	Land-use based	Same	Same
Federal Refuges	Recent historical Level 2 deliveries[f]	Firm Level 2 water needs[f]	Same
American River			
Water Rights	2004[g]	Sacramento Area Water Forum[g,h]	Same
CVP	2004[g]	Sacramento Area Water Forum (PCWA modified)[g,h]	Same
PCWA	No CVP contract water supply	35 TAF CVP contract supply diverted at the new American River PCWA Pump Station	Same
San Joaquin River[i]			
Friant Unit	Limited by contract amounts, based on current allocation policy	Same	Same
Lower Basin	Land-use based, based on district level	Same	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	Future No Action Condition Assumption	Supplemental Future Condition (#1) Assumption
	operations and constraints		
Stanislaus River	Land-use based, based on New Melones Interim Operations Plan[j]	Same	Same
South of Delta (CVP/SWP Project Facilities)			
CVP	Demand based on contracts amounts[d]	Same	Same
CCWD	124 TAF CVP contract supply and water rights[k]	195 TAF CVP contract supply and water rights[k]	Same
SWP	Demand varies based pattern used for 2004 OCAP Today studies; Table A transfers that occurred in 2005 and 2006 are not included	Demand based on full Table A amounts[e,l]	Same
Article 56	Based on 2002-2006 contractor requests	Same	Same
Article 21	MWD demand up to 100 TAF/month from December to March, total of other demands up to 84 TAF per month in all months[e,l]	MWD demand unlimited but subject to capacity to convey and deliver; KCWA demand of up to 2,555 CFS; others same as existing	Same
Federal Refuges	Recent historical Level 2 deliveries[f]	Firm Level 2 water needs[f]	Same
FACILITIES			
Systemwide	Existing facilities[a]	Same	Same
Sacramento Valley			
Shasta Lake	Existing, 4,552-TAF capacity	Same	Same
Colusa Basin	Existing conveyance and storage facilities	Same	Same
Upper American River	PCWA American River pump station not	PCWA American River pump station	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	**Future No Action Condition Assumption**	**Supplemental Future Condition (#1) Assumption**
	included	included	
Lower Sacramento River	Freeport Regional Water Project not included	Freeport Regional Water Project included	Same
Delta Region			
SWP Banks Pumping Plant	6,680 cfs capacity[a]	Same	8,500 cfs capacity[a]
CVP C.W. Bill Jones Pumping Plant (Tracy PP)	More than 4,200 cfs diversions upstream of DMC constriction	4,600 cfs capacity in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same
Los Vaqueros Reservoir	Existing storage capacity, 100 TAF, (AIP not included)	Existing storage capacity, 100 TAF; AIP included[m]	Same
San Joaquin River			
Millerton Lake (Friant Dam)	Existing, 520 TAF capacity	Same	Same
South of Delta (CVP/SWP Project Facilities)			
South Bay Aqueduct Enlargement	None	430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 diversion point	Same
California Aqueduct East Branch Enlargement	None	None	Same
WATER MANAGEMENT ACTIONS (CALFED)			
Water Transfer Supplies (available long term program)			
Phase 8	None	Supplies up to 185 TAF per year from new groundwater substitution, with 60% going to SWP and 40% to CVP[n]	Same
Lower Yuba River Accord	Not included	Not included	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	**Future No Action Condition Assumption**	**Supplemental Future Condition (#1) Assumption**
REGULATORY STANDARDS			
Trinity River			
Minimum Flow Below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF per year)	Same	Same
Trinity Reservoir End-of-September Minimum Storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same	Same
Clear Creek			
Minimum Flow Below Whiskeytown Dam	Downstream water rights, 1963 Reclamation Proposal to USFWS and NPS, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same
Upper Sacramento River			
Shasta Lake End-of-September Minimum Storage	SWRCB WR 1993 Winter-run Biological Opinion (1900 TAF)	Same	Same
Minimum Flow Below Keswick Dam	Flows for SWRCB WR 90-5 and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same
Feather River			
Minimum Flow Below Thermalito Diversion Dam	1983 DWR, DFG Agreement (600 cfs)	Same	Same
Minimum Flow Below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (750-1,700 cfs)	Same	Same
Yuba River			
Minimum Flow Below Daguerre Point Dam	Interim D-1644 Operations[o]	Same	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	Future No Action Condition Assumption	Supplemental Future Condition (#1) Assumption
American River			
Minimum Flow Below Nimbus Dam	SWRCB D-893[p] (see accompanying Operations Criteria), and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same
Minimum Flow at H Street Bridge	SWRCB D-893	Same	Same
Lower Sacramento River			
Minimum Flow Near Rio Vista	SWRCB D-1641	Same	Same
Mokelumne River			
Minimum Flow Below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)	Same	Same
Minimum Flow Below Woodbridge Div. Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)	Same	Same
Stanislaus River			
Minimum Flow Below Goodwin Dam	1987 USBR, CDFG agreement, and USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same
Minimum Dissolved Oxygen	SWRCB D-1422	Same	Same
Merced River			
Minimum Flow Below Crocker-Huffman Diversion Dam	Davis-Grunsky (180-220 cfs, Nov-Mar), Cowell Agreement, and FERC 2179 (25-100 cfs)	Same	Same
Tuolumne River			
Minimum Flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF per year)	Same	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	**Future No Action Condition Assumption**	**Supplemental Future Condition (#1) Assumption**
San Joaquin River			
San Joaquin River Below Friant Dam/Mendota Pool	None	None	None
Maximum Salinity Near Vernalis	SWRCB D-1641	Same	Same
Minimum Flow Near Vernalis	SWRCB D-1641, and Vernalis Adaptive Management Plan per San Joaquin River Agreement	Same[q]	Same[s]
Sacramento River–San Joaquin River Delta			
Delta Outflow Index (Flow and Salinity)	SWRCB D-1641	Same	Same
Delta Cross Channel Gate Operation	SWRCB D-1641	Same	Same
Delta Exports	SWRCB D-1641, USFWS discretionary use of CVPIA 3406(b)(2)	Same	Same
OPERATIONS CRITERIA: RIVER-SPECIFIC			
Upper Sacramento River			
Flow Objective For Navigation (Wilkins Slough)	3,500-5,000 cfs based on CVP water supply condition	Same	Same
American River			
Folsom Dam Flood Control	Variable 400/670 flood control diagram (without outlet modifications)	Same	Same
Flow Below Nimbus Dam	Discretionary operations criteria corresponding to SWRCB D-893 required minimum flow	Same	Same
Sacramento Area Water Forum Mitigation Water	None	Up to 47 TAF in dry years	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	Future No Action Condition Assumption	Supplemental Future Condition (#1) Assumption
Feather River			
Flow at Mouth of Feather River (Above Verona)	Maintain DFG/DWR flow target of 2,800 cfs for Apr-Sep dependent on Oroville inflow and FRSA allocation	Same	Same
Stanislaus River			
Flow Below Goodwin Dam	1997 New Melones Interim Operations Plan	Same	Same
San Joaquin River			
Salinity at Vernalis	D1641	San Joaquin River Salinity Management Plan[r]	Same
OPERATIONS CRITERIA: SYSTEMWIDE			
CVP Water Allocation			
CVP Settlement and Exchange	100% (75% in Shasta critical years)	Same	Same
CVP Refuges	100% (75% in Shasta critical years)	Same	Same
CVP Agriculture	100%-0% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same
CVP Municipal and Industrial	100%-50% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)	Same	Same
SWP Water Allocation			
North of Delta (FRSA)	Contract specific	Same	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	**Future No Action Condition Assumption**	**Supplemental Future Condition (#1) Assumption**
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement	Same	Same
CVP-SWP Coordinated Operations			
Sharing of Responsibility for In-basin-Use	1986 Coordinated Operations Agreement (2/3 of the North Bay Aqueduct diversions are considered as Delta Export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin-use)	1986 Coordinated Operations Agreement (FRWP EBMUD and 2/3 of the North Bay Aqueduct diversions are considered as Delta Export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin-use)	Same
Sharing of Surplus Flows	1986 Coordinated Operations Agreement	Same	Same
Sharing of Restricted Export Capacity for Project-specific Priority Pumping	Equal sharing of export capacity under SWRCB D-1641; use of CVPIA 3406(b)(2) restricts only CVP exports	Same	Same
Dedicated CVP Conveyance at Banks	None	SWP to convey 50 TAF per year of Level 2 refuge water supplies at Banks Pumping Plant (July and August)	SWP to convey 100 TAF/yr of Level 2 refuge water supplies at Banks Pumping Plant (July and August)
North-of-Delta Accounting Adjustments	None	CVP to provide the SWP a maximum of 37.5 TAF per year of water to meet in-basin requirements through adjustments in 1986 Coordinated Operations Agreement accounting (released from Shasta Reservoir)	CVP to provide the SWP a maximum of 75 TAF per year of water to meet in-basin requirements through adjustments in 1986 Coordinated Operations Agreement accounting (released from Shasta Reservoir)
Sharing of Export Capacity for Lesser Priority and Wheeling-related Pumping	Cross Valley Canal wheeling (max of 128 TAF/yr), CALFED ROD defined JPOD	Same	Same

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	Future No Action Condition Assumption	Supplemental Future Condition (#1) Assumption
San Luis Low Point	San Luis Reservoir is allowed to operate to a minimum storage of 100 TAF	Same	Same
CVPIA 3406(b)(2)			
Policy Decision	Per May 2003 Dept. of Interior Decision:	Same	Same
Allocation	800 TAF, 700 TAF in 40-30-30 dry years, and 600 TAF in 40-30-30 critical years	Same	Same
CVPIA 3406(b)(2) (continued)			
Actions	1995 WQCP, Upstream fish flow objectives (Oct-Jan), VAMP (Apr 15-May 15) CVP export restriction, 3,000 cfs CVP export limit in May and June (D-1485 striped bass cont.), Post-VAMP (May 16-31) CVP export restriction, Ramping of CVP export (June), Upstream Releases (Feb-Sep)	Same	Same
Accounting adjustments	Per May 2003 Interior Decision, no limit on responsibility for non-discretionary D-1641 requirements with 500 TAF target, no reset with the storage metric and no offset with the release and export metrics, 200 TAF target on costs from Oct-Jan	Same	Same

[a] A detailed description of the assumptions selection criteria and policy basis used is included in the Policy section of this Common Assumptions: Common Model Package (CACMP) report.

[b] The Sacramento Valley hydrology used in the Existing Conditions CALSIM II model reflects nominal 2005 land-use assumptions. The nominal 2005 land-use was determined by interpolation between the 1995 and projected 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects 2005 land-use assumptions developed by Reclamation to support Reclamation studies.

[c] The Sacramento Valley hydrology used in the Future No-action CALSIM II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	Future No Action Condition Assumption	Supplemental Future Condition (#1) Assumption

Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation to support Reclamation studies.

[d] CVP contract amounts have been reviewed and updated according to existing and amended contracts as appropriate. Assumptions regarding CVP agricultural and municipal and industrial service contracts and Settlement Contract amounts are documented in Table 4 (North of Delta) and 6 (South of Delta) of Appendix B: CACMP Delivery Specifications.

[e] SWP contract amounts have been reviewed and updated as appropriate. Assumptions regarding SWP agricultural and M&I contract amounts are documented in Table 2 (North of Delta) and Table 3 (South of Delta) of Appendix B: CACMP Delivery Specifications.

[f] Water needs for federal refuges have been reviewed and updated as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in Table 4 (North of Delta) and 6 (South of Delta) of Appendix B: CACMP Delivery Specifications. As part of the Water Transfers technical memorandum (Appendix A: Characterization and Quantification), incremental Level 4 refuge water needs have been documented as part of the assumptions of future water transfers.

[g] Assumptions regarding American River water rights and CVP contracts are documented in Table 5 of Appendix B: CACMP Delivery Specifications.

[h] Sacramento Area Water Forum 2025 assumptions are defined in Sacramento Water Forum's EIR. PCWA CVP contract supply is modified to be diverted at the PCWA pump station. Assumptions regarding American River water rights and CVP contracts are documented in Table 4 of Appendix B: PFCMP Delivery Specifications.

[i] The new CALSIM II representation of the San Joaquin River has been included in this model package (CALSIM II San Joaquin River Model, Reclamation, 2005). Updates to the San Joaquin River representation have been included since the preliminary model release in August 2005. In addition, a dynamic groundwater simulation is currently being developed for San Joaquin River Valley, but is not yet implemented. Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.

[j] The CACMP CALSIM II model representation for the Stanislaus River does not necessarily represent Reclamation's current or future operational policies.

[k] The Existing CVP contract is 140 TAF. The actual amount diverted is reduced due to supplies from the Los Vaqueros Project. The existing Los Vaqueros storage capacity is 100 TAF. Associated water rights for Delta excess flows are included.

[l] Table A and Article 21 deliveries into the San Francisco Bay Area Region–South and South Coast Region in the CACMP are a result of interaction between CALSIM II and LCPSIM. More information regarding LCPSIM is included in the following subsection of this document and the CALSIM-LCPSIM Integration technical memorandum (see Appendix C: Analytical Framework).

[m] The CCWD AIP is a new intake at Victoria Canal to operate as an alternate intake for Los Vaqueros Reservoir. This assumption is consistent with the future no-project condition defined by the Los Vaqueros Enlargement study team.

[n] This Phase 8 requirement is assumed to be met through Sacramento Valley Water Management Agreement Implementation.

TABLE A-1
CALSIM II Inputs
Common Assumptions: Common Model Package (Version 8D)
Sacramento Valley Conjunctive Water Management Technical Investigation Modeling Report

	Existing Condition Assumption	Future No Action Condition Assumption	Supplemental Future Condition (#1) Assumption

[o] Interim D-1644 is assumed to be implemented.

[p] Sacramento Area Water Forum Lower American River Flow Management Standard is not included in the CACMP. Reclamation has agreed in principle to the Flow Management Standard, but flow specifications are not yet available for modeling purposes.

[q] It is assumed that either VAMP, a functional equivalent, or D-1641 requirements would be in place in 2030.

[r] The CACMP CALSIM II model representation for the San Joaquin River does not explicitly implement the CALFED Salinity Management Plan.

Notes:

PCWA = Placer County Water Agency
DMC = Delta-Mendota Canal
AIP = Alternate Intake Project
TAF = thousand acre-feet
cfs = cubic feet per second
EIS = environmental impact statement
Reclamation = Bureau of Reclamation
USFWS = U.S. Fish and Wildlife Service
NPS =
CVPIA = Central Valley Project Improvement Act
SWP = State Water Project
CVP = Central Valley Project

SWRCB = State Water Resources Control Board
DWR = Department of Water Resources
FERC = Federal Energy Regulatory Commission
CDFG = California Department of Fish and Game
FRWB =
EBMUD = East Bay Municipal Utility District
ROD = Record of Decision
CALFED = Calfed Bay-Delta Program
JPOD = Joint Point of Diversion
WQCB = Water Quality Control Plan
VAMP =
CACMP =

Sources:

Vernalis Adaptive Management Plan as described and implemented in State Water Resources Control Board Revised Decision 1641, State Water Resources Control Board, March 15, 2000.

U.S. Fish and Wildlife Service. 2008. Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) at State Water Project (SWP). Memorandum from Regional Director, Fish and Wildlife Service, Region 8, Sacramento, California, to Operation Manager, Bureau of Reclamation, Central Valley Operations Office Sacramento, California. December 15. 310 pages plus 3 attachments.

Appendix C
Project Site Screening
Technical Memorandum

DRAFT TECHNICAL MEMORANDUM

DATE: October 18, 2007

TO: Sacramento Valley Conjunctive Management Project Team

FROM: NHI Technical Team

SUBJECT: DRAFT Candidate Site Screening Methodology

This memorandum is a draft summary of the methodology used to select sites for the Conjunctive Use IRWMP technical scenario development. The California Department of Water Resources and the U.S. Bureau of Reclamation (project donors) have awarded funds to Glenn Colusa Irrigation District and the Natural Heritage Institute to develop an Integrated Conjunctive Water Management Plan (ICWMP) for Northern California surface water and groundwater resources. A description of the criteria used to select sites for the Conjunctive Use IRWMP technical scenario development is summarized below. The evolution of knowledge for candidate sites considered is summarized for all technical meetings held between February 2007 and August 2007. Technical meeting notes and a draft technical memo developed by MBK are included as appendixes.

Objectives and Benefits

The three fundamental objectives driving the plan's development are:

- To improve local water supply reliability by enlarging the firm yield of the basin and enhancing water management flexibility.
- To enhance the ecosystems in the region's rivers. Healthy rivers are not just environmentally attractive, they also are central to ensuring reliable, sustainable water supplies. Water supply systems that work in concert with the environment are less likely to be encumbered by court orders, water rights hearings, and other restrictions that can have drastic effects on water supplies for farming and other economic uses.
- To allow for meeting water demands outside of the Sacramento River basin. The Sacramento River basin is already a source of much of the State's water supply. A plan that allows for well-managed and regulated water transfers is preferable to shortsighted decisions made when drought emergencies arise and water transfer revenues could help stabilize a challenged agricultural economy and provide regional economic benefits.

Methods

Conjunctive water management essentially involves the coordination of storage and withdrawal of water from surface reservoirs and groundwater aquifers to produce firm water supplies through wet and dry cycles. This general concept can be adapted in a variety of ways to increase operational flexibility both to enlarge the firm water supply and improve the environmental performance of the state and federal water projects. During the study, various reservoir reoperation scenarios will be developed and evaluated for Lakes Oroville and Shasta, the centerpieces of the State Water Project and Central Valley Projects, respectively. Additionally, the Stony Creek system will also be evaluated as another option for potential reservoir reoperation.

The region to be addressed in the integrated plan is comprised of all of the lands overlying the Lower Tuscan and interconnected groundwater formations within Butte, Glenn, Colusa and Tehama counties whose access to this groundwater could be hydrologically affected by development of the aquifer system at any location. The Sacramento Valley Conjunctive Management Technical Team (The team) began by looking for sites that fell into one of two conjunctive management operational modalities; Put-then-Take or Take-then-Put. A Put-then-Take modality involves storing surface water in a groundwater aquifer and extracting that water at a later date. This modality increases water storage space in reservoirs and increases the flexibility of water delivery quantity and timing. A Take-then-Put modality involves creating water storage space in the groundwater aquifer by extracting water that can later be refilled with surface water. Under this modality the groundwater banking operation would be given rights to surface water in storage that it can call at any time, whatever the hydrologic conditions, and require groundwater replenishment on a cycle that guarantees no interference with wells outside that water district. The goal of the site selection process was to identify at least one site for each operational modality that could be implemented through the State water project and one that could be implemented through the Central Valley project and which are sufficiently promising to warrant further analysis to develop specific operational conditions for conjunct management. The team developed screening criteria for each conjunctive management modality:

Put-then-Take Screening Criteria

1. Persistent or permanent cone(s) of depression with no seasonal recovery, (i.e. groundwater areas with available storage space) within
2. Dual use water districts that use both groundwater and surface water deliveries from the state or federal projects or within
3. Unincorporated groundwater usage areas adjacent to state or federal water districts so that the extension of the State Water Project (SWP) or Central Valley Project (CVP) into these areas is practical.

Take-then-Put Screening Criteria

1. Groundwater production areas within or adjacent to state of federal water districts areas, where groundwater extraction can be increased during drier than average years, and which are

2. A significant distance from surface water features of concern; rivers, wetlands, etc to avoid flow depletion effects, and where the dewatered aquifers

3. Can be actively recharged during wetter than average years from the state or federal reservoirs, without losing banked water, or which recover from annual infiltration.

Summary of technical meetings held on Feb 15th, 2007

At a project team meeting on February 15, 2007, nine preliminary sites were selected based on review of a Spring to Fall change groundwater contour map for 2006 made by DWR and the collective knowledge in the room regarding current operations. Five sites were selected as potential Put-then-Take sites, and four sites were selected as potential Take-then-Put sites.

a. Put-then-Take
   (1) Western Canal Water District
   (2) M & T Chico Ranch
   (3) Capay cone of depression
   (4) Cone of depression that is north of Richfield and west of Tehama
   (5) Yolo Zamora groundwater area
b. Take-then-Put
   (1) GCID—Stony Creek Fan partnership
   (2) Willow Creek Mutual Water District
   (3) Colusa County Water District
   (4) Olive Percy Davis Ranch

Summary of technical meeting held on June 19th, 2007 (See Appendix A)

For the June 19th, 2007 technical meeting MBK developed a brief description of each candidate site and how it might operate. This description was submitted to the project team in the form of a draft technical memorandum (Appendix B). For each site, current operations, current groundwater conditions, and the attributes of each water district were summarized in a table. These attributes included; general site information, operational concepts, aquifer characteristics, integration with surface water systems, infrastructure requirements, possible impacts and site screening criteria. There were several blanks in each attribute table, particularly for aquifer characteristics and potential impacts. These attributes required further research and development to be done during the full course of this study and would be used in future screening decisions. Based on each site's ability to meet the screening criteria they were either recommended to be retained for further analysis or to be dropped from the study. A brief summary of the nine sites considered is summarized below.

Put-Then-Take

WESTERN CANAL WATER DISTRICT - DURHAM CONE

Western Canal Water District (WD) extends surface water (SW) delivery system into the area overlying Durham cone of depression and operates a groundwater (GW) bank with Oroville providing the source water. One operation scenario would be to expand conjunctive management operations within Western Canal to increase surface water deliveries in wet years and reduce SW deliveries in dry years. Some of the augmented supply might be delivered to the refuges just west of Western Canal (Sac River Wildlife Refuge, Upper Butte Creek state reserve).

Groundwater levels fluctuate seasonally in response to agricultural and municipal pumping. The maximum measured fluctuation in the Chico-Durham area in 2006 was approximately 30 ft with an average value of approximately 20 ft. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from Big Chico Creek and other local streams. This site has the ability to contribute to Feather River flows and integrate with Oroville operations. It was proposed that we retain this site for further analysis.

ORLAND-ARTOIS WATER DISTRICT

Orland-Artois WD, a CVP Ag Service contractor, receives additional surface water from the Tehama-Colusa (TC) or Glen Colusa (GC) Canals, or directly from Stony Creek. Additional surface water reduces groundwater demand in current cone of depression. Water is returned to the system with additional groundwater pumping in dry years instead of Orland-Artois WD taking all or a portion of their CVP contract. (Note, the original discussion focused on this project with M&T Chico Ranch, but M&T is on east side of river while current cone of depression is on west side of the river, so a more likely project partner would be Orland-Artois WD.)

Groundwater levels fluctuate seasonally in response to agricultural pumping. The maximum measured fluctuation in the southern portion of Orland-Artois WD area in 2006 was approximately 25 ft, but appears to vary spatially due to localized pumping. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from streams tributary to Willow Creek. This site has the ability to contribute to Sacramento River flows and integrate with CVP operations. It was recommended that we retain this site for further analysis.

CAPAY RANCHO WATER DISTRICT

Capay Rancho WD would operate a groundwater bank by receiving surface water in wet years. Capay Rancho, a groundwater only district, is located over an existing cone of depression that may be utilized to store water. Methods for returning additional GW to the system in dry years are more complex, but may involve supplying water to areas in the TC Canal service area or GCID.

Groundwater levels fluctuate seasonally in response to agricultural pumping. The maximum measured fluctuation in the Capay WD area in 2006 was approximately 50 ft with an average value of approximately 25 ft. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from Stony Creek and other local streams. Note that this is right next to the Sac river, therefore may be problems with gw/sw interactions. Because there was no perceived ability to contribute to Sacramento River flows and integrate with CVP operations it was recommended that we drop this site from the study.

CORNING CANAL SERVICE AREA

A portion of the Corning Canal Service Area overlies an existing cone of depression north of Richfield and west of Tehama. The overlying districts that could operate the groundwater bank include Elder Creek, El Camino ID, Tehama Ranch, and Thomes Creek. The Corning Canal runs though these districts and typically has unutilized capacity. CVP contractors along the Corning Canal include Proberta (3.5 TAF/yr), Thomes Creek (6.4 TAF/yr), and Corning (23 TAF/yr) WDs. These WDs have recently been pumping additional GW instead of taking CVP contract water due to the relative costs of CVP water to groundwater.

Groundwater levels fluctuate seasonally in response to agricultural pumping. The maximum measured fluctuation in the Corning Canal Service Area in 2006 was in excess of 50 ft; but appears to vary spatially due to localized pumping. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from Thomes Creek, Elder Creek, and other local streams draining the western foothills. This site has the ability to contribute to Sacramento River flows and integrate with Shasta operations and it was recommended that we retain this site for further analysis.

YOLO-ZAMORA WATER DISTRICT

The Yolo-Zamora WD overlies an existing cone of depression and relies on groundwater for irrigation. Surface water could be supplied by extending the Tehama Colusa Canal or constructing a canal from the Sacramento River. This has been studied in the past but rejected as prohibitively expensive as a substitute for groundwater for irrigation. Returning water to the system may be challenging.

Unable to evaluate due to lack of data from the Central District at this time. Awaiting receipt of groundwater level data from DWR. The option of extending the Colusa Canal would be economically impractical to distribute surface water in normal and non-normal water years in addition it would be impractical to extract groundwater. There is currently no ability to contribute to Sacramento River flows and integrate with CVP operations it was recommended that this site be dropped from study.

Take-Then-Put

GLENN-COLUSA IRRIGATION DISTRICT - STONY CREEK FAN

Glenn-Colusa Irrigation District (GCID) could operate a groundwater bank in the Stony Creek Fan, banking CVP water in wet years and reducing CVP surface water deliveries in dry years. This operation may be similar to recent groundwater substitution transfers.

The northern portion of GCID represents an area known to have high aquifer transmissivity. The area is currently served by surface water. The area is underlain by the lower Tuscan Aquifer as well as shallower producing zones in the Tehama Formation. Groundwater levels in this area are shallow, generally less than 10 to 15 ft in the spring. Hydrographs suggest very little seasonal fluctuation in groundwater levels.

The southwestern portion of GCID is still relatively high, but less than that of the northern portion due to the proximity to the margin of the groundwater basin. Well yields in this area are more than sufficient to meet the demands of a take then put project. The area is currently served by surface water. Groundwater levels in this area are shallow, generally less than 5 to 15 ft in the spring. Hydrographs suggest extremely little seasonal fluctuation in groundwater levels. This sites ability to contribute to Sacramento River flows and integrate with CVP operations led to the recommendation that it be retained for further analysis.

WILLOW CREEK MUTUAL WATER DISTRICT

Willow Creek Mutual Water District (MWD) is a mixed groundwater and surface water district located between the GC Canal and the Sacramento River southeast of Willows. Willow Creek MWD is located in close proximity to the Sacramento National Wildlife Refuge. The District is small and does not have substantial agricultural areas. Groundwater characteristics were not evaluated due to proximity to the Sacramento National Wildlife Refuge. There is limited ability to contribute to Sacramento River flows and no clear way to integrate with CVP operations; therefore, it was recommended that it be dropped from the study.

COLUSA COUNTY WATER DISTRICT

Colusa County WD is a CVP Ag Service contractor that takes delivery from the southern reaches of the Tehama Colusa Canal. Some areas within the district are noted to receive both surface and GW. (Note, the original discussion included extracting the water from RD 108, but RD 108 is primarily supplied from surface water and borders the Sac River. I don't know that this is reasonable or necessary, though water banked under Colusa County WD may flow to RD 108.)

Wells to the east of I-5 indicate relatively shallow depth to water (<5 to 40 ft below ground surface [bgs]) in the spring of 2006. Depth to water increases to the west, in excess of 100 feet below ground surface along the western boundary of the water district. Wells in the eastern portion of the water district generally have higher seasonal fluctuations (up to 20 ft). Wells in the western portion of the district show little to no seasonal fluctuation in groundwater levels. Hydrographs further suggest that there is no long-term trend in groundwater levels since 2000. Aquifer transmissivity in this area decreases due to proximity to the margin of the groundwater basin. This site's ability to contribute to Sacramento River flows and integrate with Shasta operations led to the recommendation that it be retained for further study.

OLIVE PERCY DAVIS RANCH

The Olive Percy Davis Ranch (Ranch) has a Sacramento River Settlement Contract for water from the Sacramento River and CVP. The Ranch is located along the west bank of the river, east of Williams. The ranch has mixed water sources to include surface and groundwater.

Hydrographs in this area indicate that groundwater in this area is extremely shallow (up to 5 ft bgs) with very little seasonal fluctuation. Proximity to the Sacramento River could affect the implementability of a take then put project due to concerns regarding impacts on surface water resources. The aquifer in this area will likely yield large quantities of water to wells. This site has the ability to contribute to Sacramento River flows and integrate with Shasta operations. It is close in proximity to the Sacramento River and raises concerns over SW-GW interaction. Overall, it was recommended that this site be retained for further analysis.

Summary of technical meeting held on July 30, 2007 (See Appendix C)

In an attempt to identify viable put then take project sites in the northern valley, CH2MHill evaluated groundwater elevation data from the period 1970 though present. The objective of this analysis was to determine whether areas exists in the valley where cones of depression in the water table persist year-round such that they represent favorable sites where water could potentially be stored in the aquifer for later use during dry periods. The first step in the analysis was to evaluate spring-fall difference maps to look for seasonal cones of depression. Several areas with seasonal cones of depression exist, specifically the Chico-Durham area, the Capay area, and the area around the Corning Canal among others. Once areas with seasonal depressions were identified, longer term historic water level hydrographs covering the period 1970 to present were constructed for key wells defining the seasonal depressions. The results of this analysis indicated that the cones of depression were really only seasonal features, with almost complete recovery over the winter recharge period. The only exception was in some locations during the 1976-1977 and 1988-1992 drought periods. Some persistent cones of depression were suggested during these droughts but groundwater levels recovered as soon as normal rainfall returned to the valley. Overall, this groundwater level analysis suggests that no obvious locations for successful Put-then-Take scenarios exist in the northern Sacramento Valley.

Appendix A: Meeting Notes

Lower Tuscan Integrated Conjunctive Water Management Plan

Technical Team Meeting
June 19, 2007

Summary Notes

Following are brief notes from a meeting of the Lower Tuscan Technical Team at MBK Engineers on June 19th, 2007. The purpose of the meeting was to review progress on selection and screening of prospective conjunctive use sites, development of analytical tools and development of environmental flow targets.

Attendees:
Thad Bettner/GCID
Greg Thomas/NHI
Carrie Monohan/NHI
John Cain/NHI
Peter Lawson/CH2M HILL
Walter Bourez/MBK
Lee Bergfeld/MBK
Grant Davids/Davids Engineering

Site Selection and Screening

Peter presented well hydrographs from the nine candidate conjunctive management sites previously selected. He explained that while there are areas in the Sacramento Valley that experience seasonal depression of groundwater levels, these areas generally recover each year due to recharge from surrounding aquifers, precipitation, applied irrigation water, stream leakage and other sources. Contrary to initial assumption, there appear to be no areas in the valley where groundwater levels do not recover fully, except possibly in the very driest years or multi-year series. Thus finding conjunctive management sites where year-to-year groundwater banking is accomplished through initial cycles of “put” followed by “take” does not look promising. Instead, we are left with formulations where the take cycle occurs first, and recharge occurs primarily from natural sources, potentially including increased leakage from surface streams, or reduction of groundwater accretion to streams, induced by the lowering of groundwater levels.

With this sharpened perspective, it appears that promising conjunctive management sites would be irrigated areas where:

1) Surface water supplies are reliable (meaning appreciable entitlement in dry years) and form a substantial portion or all of the total irrigation water supply.

2) Underlying groundwater aquifers are productive and economically developed

3) Interaction between groundwater and surface streams, especially the Sacramento River and Feather River does not exist or is highly damped.

Given these attributes, the basic operational scenario would be to pump groundwater and forego use of an equivalent amount of surface water. The surface water could be withdrawn from storage on a schedule designed to meet environmental needs, or other needs. Another option would be to reoperate surface reservoirs to draw them down further and, if they did not refill, rely on groundwater to fill the resulting shortage. Additional yield would be produced by groundwater refilling from natural recharge or surface reservoirs refilling from water that otherwise would be released for flood control purposes.

A significant concern is the extent to which groundwater pumping affects streamflow, and when the effects occur. Effects occurring during balanced conditions would need to be addressed.

We discussed the need to revisit selection of the candidate conjunctive management sites given the additional considerations defined above, and to better document the selection criteria and process. However, no decisions were made.

Model Development

MBK demonstrated the current version of the conjunctive operations spreadsheet model, clarifying that it is still a work in progress. The basic simulation approach is to use outputs from selected CALSIM runs and impose the conjunctive operation on the CALSIM simulated conditions. The basic functionality of the model is complete, and remaining work will focus on adding data integrity and hydrogeologic characterization of the candidate sites.

The model is set up so that each of the nine sites is represented. They can be evaluated independently or in combination, although rules will be needed to establish priorities among sites for combined runs. Independent runs will be made first, and then combined runs explored.

Environmental Flows

NHI has made substantial progress toward establishing environmental flow objectives for the Sacramento River, drawing substantially on ongoing efforts by others, notably The Nature Conservancy and Stillwater Sciences. The objectives address flows for Freemont Cottonwoods, sustaining geomorphic processes, and floodplain inundation. Recognizing that the environmental flow needs may far exceed the additional supplies and timing modifications possible through conjunctive management, next steps will focus on prioritization among the Sacramento River flow objectives, and developing similar objectives for the Feather.

It was acknowledged that the existing Delta export pumping schedules pose significant constraints to reduction of Sacramento River summer flows; however, analysis of modified export schedules (such as might be possible with an isolated facility and additional south of Delta storage) are far beyond the scope of the current investigation.

Action Items

1) **Peter** to check with DWR and validate that there are no areas within the Sacramento Valley with persistent cones of depression where put-then-take operation might work.
2) **Peter** will review the nine sites identified initially, and advise the group as to whether and how site selection should be revisited, considering today's discussion and what is learned from DWR (see #1 above).
3) **Grant** will provide water balance information to Lee for GCID, Orland-Artois, and the Orland Unit.

Next Meeting

1) Next meeting is scheduled for Monday, July 30, 9:00 am at MBK.
2) Peter and Grant will meet at CH2M HILL in Redding on July 19 to discuss site selection.

Appendix B:

MBK ENGINEERS

DRAFT TECHNICAL MEMORANDUM

DATE: June 16, 2007

TO: Sacramento Valley Conjunctive Management Project Team

FROM: MBK and CH2M Hill Technical Team

SUBJECT: DRAFT Candidate Site Screening

This memorandum is a summary of nine potential project sites developed during a project team meeting at MBK Engineers on February 15, 2007. A brief description of how each site would operate and the current groundwater conditions is followed by a table listing site attributes relevant for conjunctive management and integration with the surface water system. The last section of each table summarizes the screening criteria used to rate the site to include ability to meet project objectives, volume of water that may be developed, and relative cost of developing the site. Information in the table was developed using existing data, tools, planning factors, and professional judgment to objectively evaluate all sites by consistent standards. The objective of this analysis is to screen the full list of sites and identify a maximum of six sites to carry forward in the study.

The tables are blank for several attributes, particularly for aquifer characteristics and potential impacts. These attributes will be researched and developed during the course of the study and used in future screening decisions. For example, aquifer characteristics will be determined during the next phase when water budgets are calculated for each project site. Aquifer characteristics and preliminary surface water modeling results will be used to further screen sites, and these sites may then be evaluated for possible impacts.

Western Canal Water District - Durham Cone

Project Operations

Western Canal Water District (WD) extends surface water (SW) delivery system into area overlying Durham cone of depression and operates a groundwater (GW) bank with Oroville providing the source water. An alternative operation would be to expand conjunctive management operations within Western Canal to increase surface water deliveries in wet years and reduce SW deliveries in dry years.

Current Groundwater Conditions

Groundwater levels fluctuate seasonally in response to agricultural and municipal pumping. The maximum measured fluctuation in the Chico-Durham area in 2006 was approximately 30 ft with an average value of approximately 20 ft. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from Big Chico Creek and other local streams.

Table 1: Western Canal-Durham Cone Site Attributes

General Site Information	
Project Location:	Western Canal WD and northeast of Western Canal WD near Durham
Current Water Source:	GW
Approximate Area:	? acres over Durham cone; Western Canal = 58,800 ag acres
Existing Project Contracts:	Western Canal – 145 TAF/yr Settlement, 150 TAF/yr Project
Operational Concepts	
Type of Operation:	Put-then-take
Supply (wet years):	Supply SW thru Western Canal to GW users
Return (dry years):	Pump additional GW in Western Canal to reduce SWP diversions from Feather River and Oroville
Aquifer Characteristics	
GW Recharge Concept:	In-lieu
Existing GW Levels:	Seasonally depressed
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Butte Creek
GW Quality:	Localized high Ca, NO3, and TDS in the Chico Area
Integration with SW System	
Existing:	Western Canal with SWP; Durham area is not integrated
With Project:	SWP
Reservoir:	Oroville
Infrastructure Requirements	
Supply Water:	Extend Western Canal canals to include lifts, distribution system in current GW only area
Return Water:	Additional wells in Western Canal
Possible Impacts	
Surface Water:	

Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Ability to contribute to Feather River flows and integrate with Oroville operations
Est. Water Developed:	Existing ag demands and contracts > 250 TAF/yr
Relative Cost:	Low in Western Canal only; high to include Durham area
Site Status:	**Retain for further analysis**

Orland-Artois Water District

Project Operations

Orland-Artois WD, a CVP Ag Service contractor, receives additional surface water from the Tehama-Colusa (TC) or Glen Colusa (GC) Canals, or directly from Stony Creek. Additional surface water reduces groundwater demand in current cone of depression. Water is returned to the system with additional groundwater pumping in dry years instead of Orland-Artois WD taking all or a portion of their CVP contract. (*Note, the original discussion focused on this project with M&T Chico Ranch, but M&T is on east side of river while current cone of depression is on west side of the river, so a more likely project partner would be Orland-Artois WD.)*

Current Groundwater Conditions

Groundwater levels fluctuate seasonally in response to agricultural pumping. The maximum measured fluctuation in the southern portion of Orland-Artois WD area in 2006 was approximately 25 ft, but appears to vary spatially due to localized pumping. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from streams tributary to Willow Creek.

Table 2: Orland-Artois WD Site Attributes

General Site Information	
Project Location:	Between TC and GC Canals south of Stony Creek
Current Water Source:	GW and mixed within Orland-Artois WD
Approximate Area:	? acres in cone; Orland Artois WD = 25,000 ag acres
Existing Project Contracts:	Orland-Artois WD – 53 TAF/yr CVP Ag service
Operational Concepts	
Type of Operation:	Put-then-take
Supply (wet years):	Additional SW thru TC Canal, Stony Creek, or uphill from GC Canal
Return (dry years):	Pump additional GW to reduce surface water diversions and back water into Shasta and/or Stony Creek System

Aquifer Characteristics	
GW Recharge Concept:	In-lieu and natural recharge from Stony Creek
Existing GW Levels:	Seasonally depressed
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Stony Creek and Sacramento River
GW Quality:	High nitrates occur in Arbuckle, Knights Landing, and Willows. Localized areas have high manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia, and phosphorus.
Integration with SW System	
Existing:	CVP with Orland-Artois WD
With Project:	Possibly expand integration with CVP thru TC or GC canals
Reservoirs:	Shasta (Folsom) and/or Stony Creek system
Infrastructure Requirements	
Supply Water:	Distribution system, extend canals and possibly lift water from GC canal
Return Water:	Additional wells within Orland-Artois WD; minimal to return water to GC Canal
Possible Impacts	
Surface Water:	
Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Ability to contribute to Sacramento River flows and integrate with CVP operations
Est. Water Developed:	Existing ag demands and contracts > 50 TAF/yr
Relative Cost:	Medium
Site Status:	**Retain for further analysis**

Capay Rancho Water District

Project Operations

Capay Rancho WD would operate a groundwater bank by receiving surface water in wet years. Capay Rancho, a groundwater only district, is located over an existing cone of depression that may be utilized to store water. Methods for returning additional GW to the system in dry years are more complex, but may involve supplying water to areas in the TC Canal service area or GCID.

Current Groundwater Conditions

Groundwater levels fluctuate seasonally in response to agricultural pumping. The maximum measured fluctuation in the Capay WD area in 2006 was approximately 50 ft with an average value of approximately 25 ft. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from Stony Creek and other local streams.

Table 3: Capay Rancho WD Site Attributes

General Site Information	
Project Location:	Between TC Canal and Sacramento River, north of Stony Creek
Current Water Source:	GW
Approximate Area:	? acres overlying cone; Capay Rancho WD = 7,700 ag acres
Existing Project Contracts:	None
Operational Concepts	
Type of Operation:	Put-then-take
Supply (wet years):	Provide surface water thru TC Canal, Stony Creek, or pump up from Sacramento River or head of GC Canal
Return (dry years):	Pump additional GW, possibly into GC Canal to reduce surface water diversions and back water into Shasta
Aquifer Characteristics	
GW Recharge Concept:	In-lieu and natural recharge in Stony Creek
Existing GW Levels:	Seasonally depressed
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Project borders Sacramento River, near Stony Creek
GW Quality:	The Corning Subbasin has locally high calcium.
Integration with SW System	
Existing:	None
With Project:	CVP thru TC or GC Canals
Reservoirs:	Shasta (Folsom) and/or Stony Creek system
Infrastructure Requirements	
Supply Water:	Distribution system to take surface water from nearby canals; possibly lift from Sacramento River, Stony Creek, or GC Canal
Return Water:	Conveyance to pump GW into GC or TC Canals?
Possible Impacts	
Surface Water:	
Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Currently no ability to contribute to Sacramento River flows and integrate with CVP operations
Est. Water Developed:	Small ag area (demands) and no existing contracts
Relative Cost:	Medium

Site Status:	**Drop from study**

Corning Canal Service Area

Project Operations

A portion of the Corning Canal Service Area overlies an existing cone of depression north of Richfield and west of Tehama. The overlying districts that could operate the groundwater bank include Elder Creek, El Camino ID, Tehama Ranch, and Thomes Creek. The Corning Canal runs though these districts and typically has unutilized capacity. CVP contractors along the Corning Canal include Proberta (3.5 TAF/yr), Thomes Creek (6.4 TAF/yr), and Corning (23 TAF/yr) WDs. These WDs have recently been pumping additional GW instead of taking CVP contract water due to the relative costs of CVP water to groundwater.

Current Groundwater Conditions

Groundwater levels fluctuate seasonally in response to agricultural pumping. The maximum measured fluctuation in the Corning Canal Service Area in 2006 was in excess of 50 ft; but appears to vary spatially due to localized pumping. Hydrographs from individual wells indicate that groundwater levels fully recover over the winter months. Additionally, hydrographs indicate no long-term declining trends in groundwater levels exist in this area. It is likely that the aquifer in this area receives recharge from Thomes Creek, Elder Creek, and other local streams draining the western foothills.

Table 4: Corning Canal Service Area Site Attributes

General Site Information	
Project Location:	Corning Canal service area
Current Water Source:	Mixed
Approximate Area:	? acres overlying cone of depression
Existing Project Contracts:	Corning Canal contracts total 32.9 TAF/yr
Operational Concepts	
Type of Operation:	Put-then-take
Supply (wet years):	Supply SW thru Corning Canal and possibly TC Canal
Return (dry years):	Pump additional GW to reduce surface water diversions and back water into Shasta
Aquifer Characteristics	
GW Recharge Concept:	In-lieu
Existing GW Levels:	
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Sacramento River and Thomes Creek
GW Quality:	Impairments in the Red Bluff Subbasin include high magnesium, TDS, calcium, ASAR, and phosphorus.

Integration with SW System	
Existing:	CVP Ag service contractors currently integrated
With Project:	Potential to integrate additional areas with CVP
Reservoirs:	Shasta (Folsom)
Infrastructure Requirements	
Supply Water:	Minimal in Corning Canal area; significant in existing GW only areas
Return Water:	Additional wells and conveyance?
Possible Impacts	
Surface Water:	
Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Ability to contribute to Sacramento River flows and integrate with Shasta operations
Est. Water Developed:	Existing ag demands and contracts > 30 TAF/yr
Relative Cost:	Low Corning Canal area only; High to include other areas
Site Status:	**Retain for further analysis**

Yolo-Zamora Water District

Project Operations

The Yolo-Zamora WD overlies an existing cone of depression and relies on groundwater for irrigation. Surface water could be supplied by extending the Tehama Colusa Canal or constructing a canal from the Sacramento River. This has been studied in the past but rejected as too expensive as a substitute for groundwater for irrigation. Returning water to the system may be challenging.

Current Groundwater Conditions

Unable to evaluate due to lack of data from the Central District at this time. Awaiting receipt of groundwater level data from DWR.

Table 5: Yolo-Zamora WD Site Attributes

General Site Information	
Project Location:	Between southern end of Colusa Basin Drain (CBD) and north of Cache Creek
Current Water Source:	GW
Approximate Area:	? acres overlying cone; Yolo-Zamora WD = 19,000 ag acres
Existing Project Contracts:	None

Operational Concepts	
Type of Operation:	Put-then-take
Supply (wet years):	Surface water thru TC Canal or possibly from Colusa Basin Drain
Return (dry years):	Challenging to return water to system
Aquifer Characteristics	
GW Recharge Concept:	In-lieu
Existing GW Levels:	Depressed
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Sacramento River and Cache Creek
GW Quality:	Localized areas of the Colusa Subbasin have high manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia, and phosphorus.
Integration with SW System	
Existing:	None
With Project:	Possibly with CVP
Reservoirs:	Shasta (Folsom)
Infrastructure Requirements	
Supply Water:	Extend TC Canal or CBD; distribution system within Yolo-Zamora WD
Return Water:	Unknown
Possible Impacts	
Surface Water:	
Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Currently no ability to contribute to Sacramento River flows and integrate with CVP operations
Est. Water Developed:	Significant ag area (demands) but no existing contracts
Relative Cost:	High
Site Status:	**Drop from study**

Glenn-Colusa Irrigation District - Stony Creek Fan

Project Operations

Glenn-Colusa Irrigation District (GCID) could operate a groundwater bank in the Stony Creek Fan, banking CVP water in wet years and reducing CVP surface water deliveries in dry years. This operation may be similar to recent groundwater substitution transfers.

Current Groundwater Conditions

The northern portion of GCID represents an area known to have high aquifer transmissivity. The area is currently served by surface water. The area is underlain by the lower Tuscan Aquifer as well as shallower producing zones in the Tehama Formation. Groundwater levels in this area are shallow, generally less than 10 to 15 ft in the spring. Hydrographs suggest very little seasonal fluctuation in groundwater levels.

The southwestern portion of GCID is still relatively high, but less than that of the northern portion due to the proximity to the margin of the groundwater basin. Well yields in this area are more than sufficient to meet the demands of a take then put project. The area is currently served by surface water. Groundwater levels in this area are shallow, generally less than 5 to 15 ft in the spring. Hydrographs suggest extremely little seasonal fluctuation in groundwater levels.

Table 6: GCID-Stony Creek Fan Site Attributes

General Site Information	
Project Location:	Northern portion of GCID
Current Water Source:	Primarily surface water
Approximate Area:	Estimate area within GCID overlying Stony Creek Fan
Existing Project Contracts:	GCID - 825 TAF/yr Settlement Contract
Operational Concepts	
Type of Operation:	Take-then-put
Supply (wet years):	In normal and wet years area takes existing surface water supply
Return (dry years):	Water returned to system by additional GW pumping to reduce surface water deliveries and back water into Shasta
Aquifer Characteristics	
GW Recharge Concept:	Natural
Existing GW Levels:	Shallow and stable
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Sacramento River
GW Quality:	Localized areas of the Colusa Subbasin have high manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia, and phosphorus.
Integration with SW System	
Existing:	CVP thru GCID
With Project:	No change
Reservoirs:	Shasta (Folsom); potentially Stony Creek System
Infrastructure Requirements	
Supply Water:	None
Return Water:	Additional wells
Possible Impacts	
Surface Water:	

Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Ability to contribute to Sacramento River flows and integrate with CVP operations
Est. Water Developed:	Existing ag demands and contracts > 800 TAF/yr
Relative Cost:	Low
Site Status:	**Retain for further analysis**

Willow Creek Mutual Water District

Project Operations

Willow Creek Mutual Water District (MWD) is a mixed groundwater and surface water district located between the GC Canal and the Sacramento River southeast of Willows. Willow Creek MWD is located in close proximity to the Sacramento National Wildlife Refuge. The District is small and does not have substantial agricultural areas.

Current Groundwater Conditions

Groundwater characteristics were not evaluated due to proximity to the Sacramento National Wildlife Refuge.

Table 7: Willow Creek MWD Site Attributes

General Site Information	
Project Location:	West of Willow Creek, east of Sacramento NWR and north of Delevan NWR
Current Water Source:	Mixed
Approximate Area:	Willow Creek MWD = 7,100 acres total, 2,900 ag
Existing Project Contracts:	None
Operational Concepts	
Type of Operation:	Take-then-put
Supply (wet years):	
Return (dry years):	
Aquifer Characteristics	
GW Recharge Concept:	
Existing GW Levels:	Shallow and stable
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Sacramento River
GW Quality:	Localized areas of the Colusa Subbasin have high manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia,

	and phosphorus.
Integration with SW System	
Existing:	
With Project:	
Reservoirs:	
Infrastructure Requirements	
Supply Water:	
Return Water:	
Possible Impacts	
Surface Water:	
Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Currently no ability to contribute to Sacramento River flows and integrate with CVP operations
Est. Water Developed:	Small ag area (demands) and no existing contracts
Relative Cost:	Not evaluated
Site Status:	**Drop from study**

Colusa County Water District

Project Operations

Colusa County WD is a CVP Ag Service contractor that takes delivery from the southern reaches of the Tehama Colusa Canal. Some areas within the district are noted to receive both surface and GW. (*Note, the original discussion included extracting the water from RD 108, but RD 108 is primarily supplied from surface water and borders the Sac River. I don't know that this is reasonable or necessary, though water banked under Colusa County WD may flow to RD 108.)*

Current Groundwater Conditions

Wells to the east of I-5 indicate relatively shallow depth to water (<5 to 40 ft below ground surface [bgs]) in the spring of 2006. Depth to water increases to the west, in excess of 100 feet below ground surface along the western boundary of the water district. Wells in the eastern portion of the water district generally have higher seasonal fluctuations (up to 20 ft). Wells in the western portion of the district show little to no seasonal fluctuation in groundwater levels. Hydrographs further suggest that there is no long-term trend in groundwater levels since 2000. Aquifer transmissivity in this area decreases due to proximity to the margin of the groundwater basin.

Table 8: Colusa County WD Site Attributes

General Site Information

Project Location:	Southern reaches of TC Canal, west of RD 108
Current Water Source:	Mixed
Approximate Area:	Colusa County WD = 38,000 ag acres
Existing Project Contracts:	Colusa County WD - 68 TAF/yr
Operational Concepts	
Type of Operation:	Take-then-put
Supply (wet years):	Supply additional surface water through TC Canal
Return (dry years):	Pump additional groundwater to reduce surface water deliveries and back water into Shasta
Aquifer Characteristics	
GW Recharge Concept:	In-lieu
Existing GW Levels:	Stable since 2000. Depth increases from east-west (<5 ft bgs to >100 ft bgs).
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Local streams
GW Quality:	Localized areas of the Colusa Subbasin have high manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia, and phosphorus.
Integration with SW System	
Existing:	CVP
With Project:	Expanded integration with CVP
Reservoirs:	Shasta (Folsom)
Infrastructure Requirements	
Supply Water:	Minimal
Return Water:	Minimal
Possible Impacts	
Surface Water:	
Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Ability to contribute to Sacramento River flows and integrate with Shasta operations
Est. Water Developed:	Existing ag demands and contracts > 65 TAF/yr
Relative Cost:	Inexpensive
Site Status:	**Retain for further analysis**

Olive Percy Davis Ranch

Project Operations

The Olive Percy Davis Ranch (Ranch) has a Sacramento River Settlement Contract for water from the Sacramento River and CVP. The Ranch is located along the west bank of the river, east of Williams. The ranch has mixed water sources to include surface and groundwater.

Current Groundwater Conditions

Hydrographs in this area indicate that groundwater in this area is extremely shallow (up to 5 ft bgs) with very little seasonal fluctuation. Proximity to the Sacramento River could affect the implementability of a take then put project due to concerns regarding impacts on surface water resources. The aquifer in this area will likely yield large quantities of water to wells.

Table 9: Olive Percy Ranch Site Attributes

General Site Information	
Project Location:	Between town of Williams and Sacramento River
Current Water Source:	Mixed
Approximate Area:	Ranch = 6,900 ag acres (9,110 per contract)
Existing Project Contracts:	Ranch = 31.8 TAF/yr Settlement Contract
Operational Concepts	
Type of Operation:	Take-then-put
Supply (wet years):	Supply additional surface water from Sacramento River
Return (dry years):	Pump additional groundwater to reduce surface water deliveries and back water into Shasta
Aquifer Characteristics	
GW Recharge Concept:	In-lieu
Existing GW Levels:	
Storage Capacity:	
Loss Rates:	
Stream-GW Interaction:	Sacramento River
GW Quality:	Localized areas of the Colusa Subbasin have high manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia, and phosphorus.
Integration with SW System	
Existing:	CVP
With Project:	Expanded integration with CVP
Reservoirs:	Shasta (Folsom)
Infrastructure Requirements	
Supply Water:	Potentially expand SW distribution system
Return Water:	Additional pumps?

Possible Impacts	
Surface Water:	Possible impacts to Sacramento River flows from increased GW pumping
Surrounding GW Levels:	
Subsidence:	
Sensitive Habitats:	
Site Screening Criteria	
Meets Project Objectives:	Ability to contribute to Sacramento River flows and integrate with Shasta operations; close proximity to Sacramento River raises concerns over SW-GW interaction and impacts
Est. Water Developed:	Existing ag demands and contracts > 30 TAF/yr
Relative Cost:	Inexpensive
Site Status:	**Retain for further analysis**

summary of site screening

A summary of the nine proposed sites and their respective status is provided in the following table.

Table 10: Summary of Site Status

Site Name	Status
Western Canal WD – Durham	**Retain**
Orland Artois WD	**Retain**
Capay Rancho WD	Drop
Corning Canal Service Area	**Retain**
Yolo-Zamora WD	Drop
GCID – Stony Creek Fan	**Retain**
Willow Creek MWD	Drop
Colusa County WD	**Retain**
Olive Percy Davis Ranch	**Retain**

The six sites that are retained will be carried forward for additional analysis to include calculation of water budgets, determination of aquifer characteristics, and preliminary surface water modeling.

Appendix C:

Lower Tuscan Integrated Conjunctive Water Management Plan

Technical Team Meeting
July 30, 2007

Summary Notes

Following are brief notes from a meeting of the Lower Tuscan Technical Team at MBK Engineers on July 30, 2007. These are not intended as meeting minutes, rather as a summary of key points, decisions and action items. The primary purposes of the meeting were to: 1) resolve issues related to project site selection and 2) reach consensus on the technical approach for the groundwater analysis. Environmental flows for the Feather River were also discussed. The full meeting agenda is attached.

Attendees:
Thad Bettner/GCID
Carrie Monohan/NHI
John Cain/NHI
Peter Lawson/CH2M HILL
Walter Bourez/MBK
Lee Bergfeld/MBK
Grant Davids/Davids Engineering
Maurice Hall/DWR

1. Revisit Potential "Put-then-Take" Sites

Peter reviewed the rationale that had been used to identify particular geographic areas for investigation of put-then-take (P-T) conjunctive operations. While there are areas in the Valley where cones of depression develop seasonally, those cones generally refill each year by natural recharge and therefore do not offer opportunity for inter-annual storage as is needed for conjunctive operations. Additionally, to the extent that groundwater levels in these areas do not recover completely, this tends to occur in dry years when there would be little surface water available for recharge.

Groundwater hydrographs were reviewed for three areas where seasonal cones of depression occur:

- Chico-Durham
- Capay
- Corning

Some long-term downward decline in groundwater levels is evident in some wells, but there are no persistent inter-annual cones of depression in these areas.

The Yolo-Zamora area was also discussed. Lee explained that while this area does have a local cone of depression that might be conducive to groundwater storage, there are two major shortcomings associated with this site. One is that it does not have an existing surface water supply to forego use of in dry years (and a new surface water supply would most likely be a CVP water service contract which would not provide a reliable dry year supply). The second is the need for extensive infrastructure improvements involving extension of the Tehama-Colusa Canal and construction of a completely new water distribution system.

The conclusion of the review was that there are no areas where a P-T strategy appears workable at this time on an appreciable scale. Therefore the investigation will proceed focusing on "take-then-put" (T-P) strategies, recognizing that natural recharge will play a significant role in refilling groundwater extracted for project purposes.

The degree of rigor and level of documentation needed in our screening process was discussed. It was agreed that our objective is not to conduct an exhaustive assessment of all possible conjunctive management sites in the Sac Valley, but to identify 2 or 3 most promising sites based on available information and professional judgment, and move ahead with characterization of those sites and development of our analytical tools. We also agreed that given the more detailed modeling approach we have adopted (see below), we should not conduct intermediate analyses of several sites (as originally planned) as a means of selecting the final 2 or 3.

The primary qualifications for candidate T-P sites (as discussed at our last meeting) are places where:

4) Surface water supplies are reliable (meaning appreciable entitlement in dry years) and form a substantial portion or all of the total irrigation water supply.

5) Underlying groundwater aquifers are productive and economically developed

6) Interaction between groundwater and surface streams, especially the Sacramento River and Feather River does not exist or is highly damped.

Additionally, sites that have potential to produce large quantities of groundwater are desirable.

The following three locales were discussed as having these basic attributes, and will receive primary attention as we move ahead with T-P analyses.

- Western Canal WD (potentially including the Chico-Dayton area)
- Stony Creek Fan-Northern GCID
- Central GCID

It was agreed that Carrie would spearhead documentation of our site screening and selection process. Our documentation needs to be clear that elimination of sites for our purposes at this time does not mean that those sites would not be attractive for other purposes or at other times.

2. Analytical Approaches and Tools

The ongoing Delta Vision process and its possible implications to our project were discussed at some length. It was acknowledged that it is as likely that future Delta operations will change, perhaps appreciably, as they are to remain the same. However, it was also acknowledged there is no reliable way to anticipate possible future Delta changes nor related changes to CVP and SWP reservoir operations. We agreed to continue the planned course of analysis within the context of existing Delta operating parameters. The tools and knowledge we are developing may be instructive for planning broader operational changes, but this is outside the scope of our current effort.

The three model improvement approaches formulated by CH2M HILL and MBK were discussed and a decision was made to pursue modifications to the existing superposition model (Option 3). This begins with MBK providing spatially distributed hydrologic time series to CH2M HILL for incorporation into the model. The model will be calibrated to historical groundwater levels.

The need to acknowledge and understand the nature of error and uncertainty in our analysis was discussed. Peter mentioned that sensitivity analyses could be conducted to assist in this process. We will need to track this and design appropriate analyses when we are further along.

Grant will review project budgets to identify where the necessary additional $40,000 can be found and review the necessary adjustments with GCID, NHI and DWR.

3. Environmental Flows

John and Carrie reiterated NHI’s basic approach of seeking operational changes that move toward pre-project flow regimes. This approach, rather than a species-specific approach, is thought to be most effective and defensible. Hydrographs for the Feather River were discussed. (This discussion occurred in conjunction with discussion of Item 2.)

Specific rules and priorities by month are needed to incorporate the environmental flows into the analysis. John and Carrie will work on this next.

4. Schedule

Peter, Lee and Walter will establish milestones and develop a proposed schedule for completion of technical tasks to be reviewed by the Team.

5. Summary of Action Items

- Carrie will initiate draft documentation of our site screening and selection processes drawing on the assistance of other team members as needed. A draft will be distributed before our next meeting.
- Lee to transfer hydrologic data to Peter ASAP.
- Grant to review project budgets and initiate task order revisions to CH2M HILL and MBK, in coordination with GCID, NHI and DWR, ASAP.
- John and Carrie to coordinate with Walter in expressing environmental flows in a form conducive to modeling.
- Peter, Lee and Walter will establish milestones and develop a proposed schedule for completion of technical tasks to be reviewed by the Team, ASAP.

6. Next Meeting

The next meeting was set for September 13 at 10:00 a.m. at MBK

Appendix D
Estimating Ecologically Based Flow Targets for the Sacramento and Feather Rivers

Estimating Ecologically Based Flow Targets for the Sacramento and Feather Rivers

THE NATURAL HERITAGE INSTITUTE

John Cain

Carrie Monohan

April 2008

PREFACE

This report was prepared as part of a collaborative investigation by the Glenn Colusa Irrigation District (GCID) and the Natural Heritage Institute (NHI) to explore opportunities to expand water supplies in the Sacramento Valley through conjunctive management of surface water and groundwater supplies. These expanded supplies could contribute toward achieving three primary objectives: (1) improve local in-basin water supply reliability for farms, cities, and the environment; (2) contribute to improvement of statewide water supply reliability; and (3) enhance ecosystems in the rivers in the Sacramento Valley. The investigation was funded by the California Department of Water Resources and Bureau of Reclamation.

The Scope of Work of the federal and state grants includes a task to define a range of environmental flows to restore in stream and riparian ecosystem processes to the maximum extent compatible with the protection of the interests of the riparian landowners in the floodplain improvements. Flows shall be defined for both the Sacramento River below Shasta and Keswick dams, and the Feather River below Oroville and Thermalito dams, in terms of magnitude, duration, frequency, seasonality and reach. This will be defined in a manner to avoid any uncompensated risks to affected landowners. The range may include various assumptions about levee setbacks in the floodplains. Flood-routing models will be used to estimate the potentially inundated area and system capacity to carry environmental flows.

This report was prepared by the NHI in partial fulfillment of the above-defined task. It postulates hypothetical environmental flow regimes for the Sacramento and Feather Rivers that are significantly different from those that presently exist. It is not yet known to what extent the flows can be achieved through conjunctive water management or, potentially, by other means that are outside the scope of this investigation, while other existing and future water demands are satisfied. Also, the risks that the recommended flows may pose to affected landowners are not addressed in the report, but will be addressed in subsequent work. NHI has prepared this report for the purposes of this planning investigation only. To the extent this report is used or referenced for other purposes, it will be subject to review, modification, and acceptance by the larger number of entities and stakeholders necessarily involved in crafting water management policies, projects and practices in the Sacramento Valley and downstream affected areas.

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1. EXECUTIVE SUMMARY

This study identifies an environmental flow regime for the Sacramento and the Feather Rivers in order to:

- Test the feasibility of reoperating terminal reservoirs in the Sacramento River Basin without diverting additional water away from agriculture,
- Develop a comprehensive hypothesis regarding the range of flows that may be necessary to restore ecological processes to the Sacramento River, and
- Use the environmental flow targets to inform and guide conjunctive use scenarios.

The development of environmental flow regimes is as much an art as a science, but we attempted, to the extent possible, to use established methods to develop a transparent and replicable approach for identifying and environmental flow regime. We conducted a detailed literature review of various methods and approaches previously utilized to develop environmental flow recommendations, and employ a version of the holistic approach practiced in South Africa and Australia (King et. al. 2000) to identify an environmental flow regime for the Sacramento and Feather Rivers. This approach relies heavily on hydrological evaluations, previous studies and modeling efforts analysis of historical hydrology, and expert opinion to estimate environmental flow requirements.

Our approach consists of five basic steps:

1. Identify specific environmental objectives (i.e,. target species, aquatic and riparian communities, and desired ecological conditions that are flow dependent).
2. Approximate the timing, magnitude, frequency, and duration (TMDF) of flows necessary to support achieve environmental objectives.
3. Compare and analyze existing and historical hydrology to understand natural hydrologic patterns and how they have been altered.
4. Identify obvious gaps between flows necessary to achieve objectives and existing flows.
5. Modify the existing hydrograph into an environmental flow hydrograph based on an understanding of natural hydrology and the flows necessary to achieve key objectives.

These five steps will ultimately need to be followed by an adaptive management research program to test and refine an improved environmental flow regime over time.

We designed the environmental hydrograph to achieve the following three types of objectives

- Geomorphic Functionality: Bed mobility, channel migration, and floodplain inundation.

- Riparian Habitat Sustainability: Recruitment and maintenance of Fremont Cottonwood.
- Chinook Salmon: Improved habitat, particularly rearing habitat, for all runs.

We relied on field data, modeling results, and studies , particularly the recent Nature Conservancy Study of the Sacramento River, to identify the minimum flows and critical thresholds to achieve each of our objectives. We then analyzed historical and existing hydrology to understand how the objectives may have been achieved under pre-dam conditions and to evaluate how existing hydrology may fall short of meeting those objectives.

A sharp reduction in the magnitude and duration of the late winter and early spring hydrograph and a corresponding reduction of inundated floodplain habitat is the most obvious and significant change in the hydrograph on both the Sacramento and Feather Rivers. The reduction in late winter and spring flows reduces the frequency of geomorphic and riparian flows and substantially reduces the extent and frequency of occurrence of inundated floodplain rearing habitat for salmonids. Restoring spring flows alone, however, will not be sufficient to dramatically increase the amount of floodplain habitat. Modifications of the levees and bypass system will also be necessary to enable high flows to inundate historical floodplains. We evaluate the amount of flow necessary to inundate the Yolo and Sutter Bypasses assuming modification of the weirs controlling flows into those bypasses in the interest of identifying water efficient strategies for creating large areas of inundated floodplain habitat.

The last chapter identifies an environmental flow regime for the Sacramento and Feather Rivers. An increase in late winter and early spring flow is the primary component of the environmental flow regime, but a corresponding reduction in summer base flows is also recommended. Reduced summer flows are primarily needed to free-up water needed to restore the spring hydrograph but may also provide ecological benefits by better approximating the natural hydrograph. Reducing summer base flows could, however, increase summer temperatures and harm salmonids including the endangered winter-run Chinook salmon. On the other hand, cool water temperatures in the upper Sacramento River are largely controlled by the volume of cold water storage behind Shasta Dam and the environmental flow regime identified here does not involve modifying coldwater pool management.

The summer temperature issue is one of several key uncertainties that must be addressed before any significant modifications to the flow regime can be refined and implemented for environmental purposes. Articulating a hypothetical environmental flow regime is the first step in identifying and addressing constraints and uncertainties associated with improving environmental flow regimes on regulated rivers. To that end, NHI welcomes comments and criticisms so that we can improve upon this report as we learn more about the rivers and the people who depend upon them for their livelihood.

2. INTRODUCTION

This study identifies environmental flow targets for the Sacramento River and the Feather River. The purpose of developing environmental flow targets is to:

- Test the feasibility of reoperating terminal reservoirs in the Sacramento River Basin without diverting additional water away from agriculture,
- Develop a comprehensive hypothesis regarding the range of flows that may be necessary to restore ecological processes to the Sacramento River, and
- Use the environmental flow targets to inform and guide conjunctive use scenarios.

Our thesis is that reservoirs operated today for a limited set of water supply and flood control objectives could be reoperated to achieve newly defined ecological objectives without compromising existing objectives. This opportunity was recognized by the authors of CALFED's Strategic Plan for Ecosystem Restoration:

> "There is underutilized potential to modify reservoir operations rules to create more dynamic, natural high-flow regimes in regulated rivers without seriously impinging the water storage purposes for which the reservoir was constructed. Water release operating rules could be changed to ensure greater variability of flow, provide adequate spring flows for riparian vegetation establishment, simulate effects of natural floods in scouring riverbeds and creating point bars, and increase the frequency and duration of overflow onto adjacent floodplains."

Clearly defining this new set of ecological objectives and estimating the flows necessary to achieve them is the first step toward evaluating the feasibility of restoring these flows. The biological and physical processes that support natural riverine functions are complex and the task of defining environmental flow regimes is enormously difficult. For the purpose of defining an environmental flow regime and assessing the feasibility of attaining it, we have identified a simplified but broad set of water intensive ecological objectives that best capture the full range and magnitude of environmental flow requirements in the Sacramento Basin. These objectives include:

- Geomorphic Processes: sediment transport, channel geomorphology, floodplain inundation.
- Riparian vegetation: cottonwood recruitment and maintenance flows
- Chinook and Steelhead: stream temperatures and adequate flow for various life stages.

This study focuses on the magnitude and timing of flows necessary to replicate key ecological and geomorphic processes, and considers the flows necessary to provide suitable conditions for various life stages of Chinook salmon and steelhead. This study does not identify specific population targets for salmonid restoration, nor does it address important non-flow objectives such as habitat area required for restoration of target species or augmentation of coarse sediment supplies necessary to restore full geomorphic structure and function. Rather this study focuses on magnitude, pattern, and quantity of water necessary to restore ecological functions assuming that adequate physical habitat exists or will be created to complement a suitable environmental flow regime. The rationale of this focus is to identify a hypothetical environmental flow regime for the purpose of evaluating whether it is possible to reestablish ecological and geomorphic flows on the rivers of the Sacramento Basin without reducing water supply deliveries to existing water users.

This report would not have been possible without the foundational analysis conducted by the Nature Conservancy and their consulting team, but it differs substantially from the Sacramento River Ecological Flows Study (SREFS) developed by the Nature Conservancy with funding from the CALFED Bay-Delta Program. The SREFS compiled information on the state of the Sacramento River ecosystem and developed a decision support tool to predict how changes in the flow regime of the Sacramento River might affect key attributes and species of the riverine ecosystem. The SREFS did not, however, attempt to develop an environmental flow prescription for the river and did not address ecological conditions or flow requirements for the Feather River. The SREFS decision support tool could be used to test and refine the flow regime developed for this report, but the SREFS did not and will not propose an environmental flow regime. We relied heavily on the information developed for the SREFS to generate the environmental flow regime described in this report.

Our study relies heavily on analysis of historical hydrology and the habitat it created to provide a reference point for identifying ecosystem restoration goals, but we recognize that it is not possible to restore historic conditions in highly altered systems such as the Sacramento River. Historical hydrologic analysis is useful for identifying patterns in the timing, magnitude, duration, and frequency of flows that may be important for maintaining native species, but it is less useful in developing specific flow prescriptions, because physical habitat has been so profoundly changed by dams and levees. We recognize that it is not possible to fully restore historical hydrology or habitat conditions in the Sacramento Valley, but ecosystem restoration will require reestablishment of a minimum threshold of both hydrologic and physical habitat conditions.

Although this study identifies hypothetical restoration flow regimes for the Sacramento and Feather Rivers, we recognize that the most reliable method for developing a restoration flow regime is through a long-term adaptive management program including a series of trials that test the effectiveness of various flow prescriptions. The hypothetical flow regime serves as a reasonable starting point for evaluating the economic feasibility of reoperating reservoirs and a long-term adaptive management program. The assumptions and uncertainties associated with the hypothetical flow regime are important to acknowledge and understand. To cost effectively achieve restoration, managers will ultimately need to test these assumptions and limit the uncertainties through an adaptive management program consisting of a combination of modeling, pilot flow studies, model calibration, and long-term implementation.

3. METHOD FOR DEVELOPING ENVIRONMENTAL FLOW RECOMMENDATIONS FOR THE SACRAMENTO AND FEATHER RIVERS

We conducted a detailed literature review of various methods and approaches previously utilized to develop environmental flow recommendations, which is described in further detail in Appendix A. We have employed a version of the holistic approach practiced in South Africa and Australia (King et. al. 2000) to identify an environmental flow regime for the Sacramento River. This approach relies heavily on hydrological evaluations, previous studies, and expert opinion to estimate environmental flow requirements and develop a long-term adaptive management plan for implementing and refining an environmental flow regime over time. The results of the holistic approach provide a framework for increasing knowledge regarding the relationship between flow and environmental objectives and refining water management practices over time. The output of the holistic method envisioned here provides not only an estimate of environmental flow requirements, but more importantly, an explicit identification of key assumptions and uncertainties that need to be tested overtime to more accurately describe the flow requirements necessary to achieve environmental objectives.

We made two important assumptions in generally applying this method to the Sacramento River.

- Similarities in both the restoration objectives and the hydrologic, geomorphic, and ecological conditions on the Sacramento River will result in relatively similar prescriptions for environmental management flows. We believe this assumption is well supported by the environmental conditions and historical alteration of this river.

- The flow necessary to achieve restoration objectives may vary greatly depending on non-flow restoration actions such as improving spawning habitat, reconstructing degraded channel, removing levees to restore floodplain habitat, modifying and screening water diversions, reducing polluted run-off, managing ocean harvest, and other factors. In general, non-flow restoration actions will reduce the amount of water necessary to achieve restoration objectives.

The holistic approach applied in this study consists of the following 6-step process to identify an environmental flow regime:

1. Identify specific environmental objectives (i.e,. target species, aquatic and riparian communities, and desired ecological conditions that are flow dependent).
2. Approximate the timing, magnitude, frequency, and duration (TMDF) of flows necessary to support target species, communities and desired ecological processes.
3. Compare existing vs. historical hydrology to understand natural hydrologic patterns and how they have been altered.

4. Identify obvious gaps between objective flow requirements and existing flows.
5. Develop an environmental flow hydrograph to achieve ecological objectives based upon a clear understanding of historical and existing hydrologic patterns, and identify key hypotheses and uncertainties regarding the relationship between flow patterns and environmental objectives.
6. Design an adaptive management program to further test and refine environmental flows.

1) Identify specific environmental objectives (i.e,. target species, aquatic and riparian communities, and desired ecological conditions that are flow dependent).

Well-articulated target ecological conditions and desired species and communities are necessary for establishing environmental flows. Despite the correctly vogue concept of restoring ecosystem processes and avoiding species specific approaches, there is no getting around the fact that key species need specific hydrologic conditions at specific times. This analysis will include both aquatic and riparian communities and the flow parameters necessary to sustain these communities such as floodplain inundation, appropriate water temperature, or creation of structural habitat through geomorphic processes. These specific environmental objectives may vary by region, sub-basin, and reach of the river.

2) Approximate the timing, magnitude, frequency, and duration (TMDF) of flows necessary to support target species, communities and desired ecological processes.

An environmental flow regime encompasses the adequate timing, magnitude, duration, and frequency of flows necessary to support target species and facilitate specific ecological processes encompassed in the stated environmental objectives. Where we understand the life cycle timing of various target species, it is relatively easy to identify the approximate timing and duration of flows necessary to support different life stages of target species. Estimating the required flow magnitude is far more difficult but can be informed by field data, results of numerical models, and general relationships described in the literature. Most short lived target species require adequate flows each year to reproduce, while longer lived species can sustain their populations with a lower frequency of flow conditions conducive to reproduction. For example, riparian forest species may only require recruitment flows every five to ten years to establish new seedlings.

Estimating the magnitude of flows necessary to support or optimize conditions for target species and processes is by far the most difficult element of the environmental hydrograph to approximate. Environmental engineers and biologists have developed relatively elaborate methods for determining ideal flow regimes such as physical habitat simulation (PHABSIM) and Instream Incremental Flow Methodology (IFIM) to identify optimum flow magnitudes based on known habitat preferences of target species, measured habitat conditions (velocity and depth) at various flows, and numerical models that predict habitat conditions at a range of flows. Numerical models that describe the width, depth, and velocity of the rivers at various discharges are useful for predicting river stage and temperature at various locations, factors that are important considerations for habitat or facilitating geomorphic and hydrologic processes. As discussed above, these models tend to focus on the needs of specific species and can sometimes produce results that are inconsistent with both holistic ecological process restoration and common sense. Furthermore, these models are often not calibrated, particularly at higher flows relevant to riparian recruitment, geomorphic processes, and spring outmigration temperatures. Nevertheless, we utilized the results of these models as a guide combined with other information to develop our environmental flow management hypothesis.

Where possible, we relied on actual data and measurements to estimate the flows necessary to achieve suitable conditions to support biological, riparian, and geomorphic objectives for temperature, floodplain inundation, and bed mobilization. In particular, we relied on USGS temperature gauges to characterize the relationship between temperature and flow. Similarly, we relied on previous studies of the rivers to characterize flows necessary to mobilize bed material and inundate the floodplain.

3) Compare existing vs. historical hydrology to understand natural hydrologic patterns and how they have been altered.

Analyses of historical hydrologic data is useful for describing natural patterns and identifying potential links between hydrology and the requirements necessary to maintain species and precipitate key processes. An analysis of historical patterns can provide clues about the timing, magnitude, duration, and frequency of flows under which target species have evolved. Identification of major changes between historical and hydrologic patterns combined with the life history requirements of various species can help generate hypotheses about how flow regulation may be limiting target species. We will use the an analysis similar to the Index of Hydrologic Alteration approach (Richter et al. 1996) and the Hydrograph Component Analysis (HCA) (Trush et al. 2000) to evaluate changes in flow patterns. The analysis similar to the IHA provides a quick statistical overview of how several important hydrologic attributes have changed. The analysis similar to the Hydrograph Component Analysis (HCA) method developed by McBain and Trush provides a detailed graphical analysis of historical and existing hydrologic conditions. While valid and useful, the statistical analysis in the IHA method is not substitute for visually comparing and evaluating key components of the pre- and post-dam hydrographs. Similarly, visual comparisons of pre- and post-alteration hydrographs don’t always reveal important changes identified by the IHA method.

4) Identify obvious gaps between objective flow requirements and existing flows.

An analysis of historical flow patterns combined with an approximation of the TMDF of flows necessary to achieve objectives compared with the regulated flow regime can help illustrate obvious gaps between regulated flows and flows that may be necessary to achieve environmental objectives. We will plot TMDF flow requirements developed in Step 2 as an annual hydrograph and compare it with average regulated and historical conditions.

5) Develop an environmental flow hydrograph to achieve ecological objectives based upon a clear understanding of historical and existing hydrologic patterns, and identify key hypotheses and uncertainties regarding the relationship between flow patterns and environmental objectives.

This project identifies hypothetical restoration flow regimes but recognizes that the most reliable method for developing a restoration flow regime is through a long-term adaptive management program including a series of trials that test the effectiveness of various flow prescriptions. The purpose of developing the hypothetical flow regime is to develop a comprehensive hypothesis regarding the range of flows that may be necessary to restore ecological processes to the Sacramento River. However, the assumptions and uncertainties associated with the hypothetical flow regime are as important as the flow regime itself.

6) Design an adaptive management program to further test and refine environmental flows.

To cost effectively achieve restoration, managers will ultimately need to test these assumptions and limit the uncertainties through an adaptive management program consisting of a combination of numerical modeling, pilot flow studies, model calibration, and long-term restoration implementation.

4. IDENTIFY ENVIRONMENTAL OBJECTIVES AND UNDERLYING CONCEPTUAL MODELS

4.1. Environmental Objectives

The geomorphic, riparian, and salmonid objectives considered in this report are summarized below. A more detailed description of the objectives, background information, and the underlying conceptual models is included in Appendix B.

Geomorphic Objectives

- Sediment Transport: bed mobilization and bed scour
- Channel Migration
- Floodplain Processes: inundation and fine sediment deposition

Riparian Objectives

- Fremont cottonwood seedbed preparation
- Fremont cottonwood seed germination
- Fremont cottonwood seedling growth
- Periodic large-scale disturbance of the riparian zone
- Riparian stand structure and diversity

Chinook Objectives

- Chinnook salmon: suitable flow conditions and temperatures for all life stages.
- Provide inundated floodplain habitat for rearing juveniles during the later winter and early spring.
- Maintain and recruit spawning habitat, but avoid scouring gravels while eggs or alevon are present

We purposely did not identify population targets for salmonids. The extent and magnitude of restoration actions depends on the size of the population fish managers are attempting to restore. More fish require presumably require more habitat particularly for spawning and rearing. Creating more habitat may require both physical changes in channel conditions and increased flows. .

Appendix B describes the underlying assumptions and rationale (conceptual model) for environmental flow requirements. It describes the science of how and why river flows are necessary to achieve the objectives listed above, and identifies some of the challenges associated with developing environmental flow prescriptions.

5. ENVIRONMENTAL FLOW THRESHOLDS AND REQUIREMENTS

5.1 Geomorphic Thresholds

Flow requirements broadly fall into two categories: threshold and targets. Thresholds are flow prescriptions that only achieve their objective if the threshold is reached or exceeded. For example, bed mobility flows must be high enough to mobilize the bed. If they are below the threshold, the bed does not mobilize and no progress toward the objective occurs. In actuality, however, bed mobilization may occur at different flows in different reaches making it difficult if not impossible to name a single threshold number. Targets are flow requirements that are desirable but not essential to achieve. Benefits still accrue when there is progress toward the target even though the target is not actually reached. For example, a flow release to meet a target of 5,000 cfs to achieve an optimal water temperature for twenty four hours a day will still provide temperature benefits even if the release only achieves 4,000 cfs and optimal water temperatures eighteen hours per day. At some point, however, there is a minimum threshold or minimum flow below which temperatures are lethal or flows are insufficient to support fish.

This paper focuses on thresholds for key ecological and geomorphic objectives that generally require high flow thresholds, but also identifies flow targets to sustain salmon. We have not attempted to define minimum flow thresholds for salmon, but rather have identified more generous targets based on historical base flow conditions. We identify the basis for these thresholds and targets in this section and compile them into a environmental hydrograph in the final chapter of this report.

For each threshold, we have estimated the magnitude, duration, frequency, and timing of flows necessary to achieve a desired outcome and have organized table X and the following text accordingly.

5.1.1. Bed Mobilization:

Magnitude: There is limited information regarding the magnitude of flows required to initiate bed mobilization on the Sacramento River, but less information regarding flows necessary to precipitate full-scale bed mobilization. Under natural conditions the gravel bedded reaches of the Sacramento River were theoretically mobilized by peak flows exceeding the 1.5 to 2 year recurrence interval of the annual instantaneous peak (Leopold et al 1964), which is approximately 80,000 cfs to 120,000 cfs. For comparison, the post dam Q1.5 and 2.0 recurrence interval flow is approximately 65,000 and 80,000 cfs respectively. The Department of Water Resources estimated that the threshold for spawning gravel mobilization immediately below Keswick Dam was 50,000 cfs (CDWR 1981), but this is considered to be a minimum because it was based on observations of gravel that was artificially deposited below the dam *(Stillwater,*

> *2006).*[1] DWR added 13,300 yd^3 of gravel below Keswick Dam in 1978 and 1979, and estimated that 85% of it was eroded by high flows of 36,000 and 50,000 cfs during the winter of 1980 (CDWR 1981). Latter, Koll Buer of the USBR measured mobility and transport downstream of Keswick with "flower box" samplers – boxes placed into the channel bed before a high flow event. Buer's measurements indicate that gravel transport begins at 24,000 cfs but did not provide information about when larger gravels and the entire bed begin to mobilize. The coarser riffles downstream of Keswick (small boulders and large cobbles) are probably armored due to years of erosion from sediment free water released from Shasta Dam. These armored riffles appear not to change and thus probably remain immobile even at flows exceeding 100,000 cfs (K. Buer, personal communication in Kondolf, 2000).

There are not empirical studies or observations regarding bed mobility on the Feather River. Historical flow data is the only information available to estimate the discharge necessary to mobilize the bed on the Feather River. The 1.5 to 2 year recurrence interval of the annual instantaneous peak prior to the construction of Oroville Dam was 33,000 to 50,000 cfs respectively.

> *Frequency:* Relatively frequent bed mobilization is necessary to prevent vegetation establishment and encroachment on gravel bars. Willows can become well established and resistant to scour in three to four years (cite). Therefore, bed mobilization flows are necessary at a greater frequency then every three to four years to prevent vegetation establishment.
>
> *Duration:* The duration of peak flows may vary depending on the objective. A short duration may be enough to clean gravels on a spawning riffle while a longer duration flow may be necessary to maintain overall transport of gravels. Because coarse sediment inputs are limited by the upstream dam and riffles already show signs of armoring, long duration peak flows may actually degrade riffles. For this reason and to both reduce flood hazards and economize water, a short duration bed mobilization flow of approximately 12 hours at the recommended peak flow and then ramping down thereafter consistent with historical patterns may be optimal.
>
> *Timing:* Ideally, bed mobility flows should occur after fall run fry have emerged from the gravel and before swallows begin nesting on stream banks in late march. We therefore recommend a 30 day target window between February 20 and March 20.

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[1] These gravels may have mobilized at lower flows because of their unnatural position relative to the high flows or because they were not integrated into the gravel/cobble matrix of the natural bed

5.1.2 Bed Scour

Less is known about the bed scour process, flows exceeding the natural 5–10 year recurrence interval are probably necessary to precipitate bed scour (Trush et al. 2000). The pre-dam Q5 and Q10 recurrence interval on the Sacramento are 150,000 and 200,000 cfs respectively. During the post dam era, flows of 150,000 cfs or more occurred roughly once every 10 years. On the Feather River, the pre-dam Q5 and Q10 were 104,000 and 144,000 respectively. Flows of this magnitude have only occurred twice in the forty years since Oroville Dam was constructed. Because of the lack of information regarding bed scour and the probable flooding impacts of these flows, it is exceptionally difficult to develop and achieve a bed scour flow recommendation.

5.1.3 Bank Erosion and Channel Migration

Magnitude

Stillwater reports that there is general disagreement on the exact magnitude of flow to initiate substantial bank erosion, but claims there is growing evidence that flows between 20,000 and 25,000 cfs will erode some banks while flows above 50,000 to 60,000 cfs are likely to cause widespread bank erosion (Stillwater, 2007). Meander migration modeling analysis for the Sacramento River assumed that 15,000 cfs was the lower threshold for meander migration (Larsen, 2007). Total bank erosion and channel migration, however, is dependent on both the duration and magnitude of flows, which together produce a cumulative streampower in any given year. Analysis of cross section surveys (Buer, 1994a) over more than ten years shows that rates of bank erosion are closely correlated with cumulative annual stream power (Larsen, et al., unpublished in Stillwater, 2006). Bank erosion.

On the Feather River, there is very little information regarding flows necessary to initiate bank erosion and channel migration. The pre-dam Q1.5 on the Feather River (35,000 cfs) is approximately forty four percent of the pre-dam Q 1.5 on the Sacramento River (80,000) cfs. If channel migration flows on the Feather were similarly proportioned channel migration flows on the Sacramento (50,000 – 60,000 cfs), then one could expect significant and wide spread bank erosion on the Feather River at flows between 20,000 and 25,000 cfs. Instantaneous peak flows of this magnitude reoccur every 2.5 years on average, and large areas of channel revetment along the Feather River indicate that the unprotected bank is subject to erosion under the current flow regime.

Duration

The stream power relationship between magnitude and duration make it difficult to identify a specific threshold. Without modeling analysis, it is difficult to assess whether two weeks at 30,000 cfs could result in as much bank erosion as two days at 60,000 cfs.

Frequency

Bank erosion and channel migration are important for maintaining general riparian habitat, nesting habitat for bank swallows, and turbidity for juvenile fish cover. We are uncertain how often migration and erosion should occur but suspect that some bank erosion every year is a reasonable target. Slight but annual bank erosion may be beneficial for maintaining optimal bank swallow habitat. More significant and annual erosion events may be necessary for producing turbid water conditions. Moderate but less frequent bank erosion, every (2-4) years, may be adequate for generating new riparian habitat.

Timing
Erosive flows during the bank swallow nesting period, which generally begins in late March, can actually disrupt bank swallows. Therefore, it may be most beneficial to bank swallows to achieve bank erosion objectives prior to late march.

5.1.4 Floodplain Inundation and Rearing Habitat Flows

The occurrence of inundated floodplain habitat has been substantially altered by both levees and dams. Dams have reduced the frequency of high flows sufficient to inundate floodplains, while levees have prevented high flows, even very high flows, from inundating floodplains particularly in the lower reaches of the river below Colusa. It is not reasonable to reestablish inundated floodplains by overtopping levees, because it would require extremely, even unnaturally, high flows and would cause widespread flood damage.

Adequate duration of flooding in the designated flood bypasses generally occurs in the wet years and sometimes in normal wet years creating excellent conditions for salmon and splittail. But overtopping the weirs and flooding the bypasses in normal dry and dry years would require prohibitive amounts of water to achieve in normal dry and dry years. For efficiency sake, it is probably only realistic to achieve prolonged (30-60 days) floodplain inundation in normal dry and dry years by notching (or removing) the upstream weirs to allow a small amount of water to pass (3,000-5,000 cfs) and installing inflatable weirs in the low flow channels of the bypasses to back-up water.

Strategically breaching levees and flood control weirs to inundate flood bypasses and other undeveloped land is a much more prudent and achievable approach for creating inundated habitat. Although there may be many places to create inundated flood plain habitat with strategic levee modifications, we have focused on identifying flows that would create inundated habitat in the Yolo and Sutter Bypasses if modifications are made to the weirs that control flow onto the bypass. The area of inundation under a given flow is determined by topography and drainage. We assume changes in the topography and drainage of the bypasses (i.e. berms or inflatable wiers) to maximize the area of inundation at lower flows and minimize the potential for stranding. While it might be possible to create large areas of habitat at low flows, more flows may be necessary to optimize temperatures on the flood plain and conveyance of nutrients from the floodplain to the Delta.

Magnitude
We evaluated two questions associated with magnitude: the magnitude of flow necessary in the Sacramento or Feather Rivers necessary to inundate the bypasses and the magnitude of flow in the bypasses necessary to create large areas of suitable floodplain

habitat. It may be possible to inundate large areas of the bypass with relatively little flow by installing flow barriers in the bypass to back-up water onto the floodplain. While this may be suitable for creating large areas of inundation, it might not create the right residence time and temperature for optimal habitat. Habitat characteristics such as velocity, depth, temperature, residence time, primary productivity are negatively correlated with flow, while Diptera, an important food resource, was positively correlated with flow (Sommer et al, 2004).

According to DWR modeling analysis, large areas of the bypass become inundated with as little as 5,000 cfs flowing through the bypass (figure 5.1) (Harrell, B., 2008). Flows in excess of 25,000 cfs in the Sacramento River, however, may be necessary before it is possible to get 5,000 cfs down the bypass.

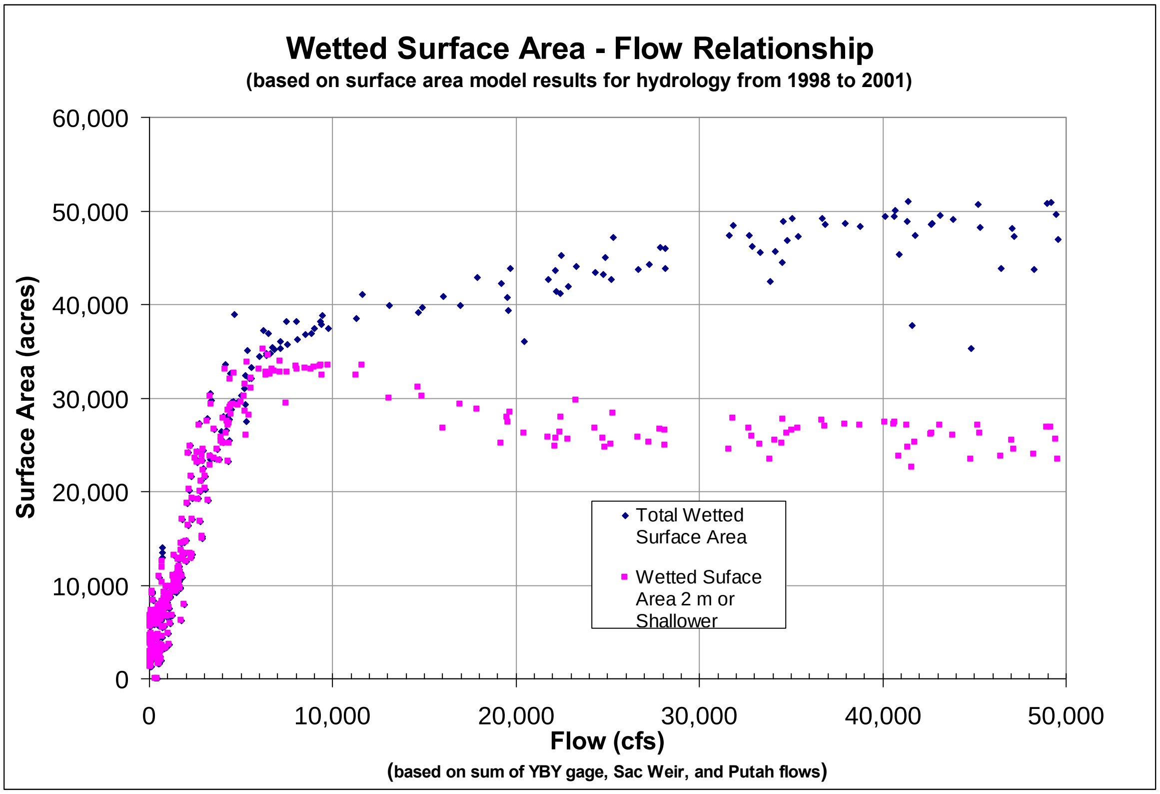


Figure 5.1: Wetter surface area-flow relationship for flows in the Yolo bypass (cite)

To estimate the amount of flow necessary to inundate the Sutter and Yolo Bypasses, we referred to USGS topographic maps to determine ground elevations at Tisdale and Freemont weirs which currently control flows onto the bypass, and then used stage discharge relationships for nearby gauges to estimate the amount of flow necessary to achieve a stage equal to the ground elevation at the weir – an overbank flow assuming the weir did not exist or was operable (table 5.1). The overbank flow, however, is not enough to push substantial amount of water down the bypasses. We therefore assumed that a minimum of 5,000 to 10,000 cfs above the overbank flow was necessary to create substantial inundated floodplain in the bypass.

Table 5.2 identifies flow recommendations for various year types at four key sites: Tisdale Weir, Freemont Weir, and Verona Gauge on the Sacramento River and Nicolaus Gauge on the Feather River. Tisdale Weir spills into the Sutter Bypass and then flows back into the Sacramento River near Freemont Weir. The sum of Freemont and Nicolaus should equal Verona. Note, however, that table 5.1 flows at Verona are lower then the sum of Freemont and Nicolaus. This is because large amounts of the Sutter Bypass (ground elevation of 25 feet) will flood with backwater from the Sacramento at flows above 27,000 cfs at Freemont Weir. In other words, if Freemont or Verona is greater then 30,000 cfs, then large amounts of the Sutter Bypass are flooded irregardless of flows in the Feather River or at Tisdale Weir.

Table 5.1: Overbank flows in the Yolo or Sutter Bypass assuming levees or weirs along the Sacramento and Feather Rivers are breached or removed

Gauge or Weir	Ground Elevation	Overbank Flow	Notes
Nicolaus Gauge (Feather)	30	10,500	
Freemont Weir	25	27,000	Approximate based on Verona Gauge
Freemont with Excavation	13	15,000	Invert of the Toe Drain
Tisdale Weir	40	25,000	Approximate
Sacramento Wier (I Street Bridge)	15	49,000	
Sac Weir with Excavation	10	31,000	Sac Weir with excavation
Right Bank at Verona	25	42,000	Remove right bank levee

Table 5.2: Recommended flows to create inundated floodplain habitat in the Yolo and Sutter Bypasses for various year types.

	Year Type				
	C	D	BN	AN	W
Nicolaus (Feather)			12,000	15,000	20,000
Freemont Wier		25,000	30,000	37,500	45,000
Tisdale Weir		25,000	30,000	35,000	40,000
Verona		25,000	35,000	45,000	55,000

Duration and Timing

Provide floodplain inundation flows for 30 – 60 days between February 15 and April 30 into Sutter and Yolo Bypasses to provide rearing habitat for salmon and splittail and spawning habitat for splittail. Where possible, time releases to coincide with and extend duration of high releases on the Yuba and Sacramento.

Frequency

Ideally, it would be possible to inundate the bypass in every year to enhance foodweb productivity and improve rearing habitat for every year class of salmon. It may be possible to do this while economizing on water by inundating relatively small areas in dry years and very large areas in wet years with no inundation in critical dry years.

5.2 Riparian Flow Requirements

A sequence of hydrologic, geomorphic, and biologic phenomena is necessary to recruit cottonwood seedlings to the riparian forest. Under natural flow regimes, moderate 5- to 10-year flood events precipitate channel migration and the creation of point bars suitable for cottonwood seedling establishment (McBain and Trush 2000, Trush et al. 2000). Analysis of hydrologic data, dendrochronologic data, historic channel mapping, and aerial photography riparian recruitment appears to occur approximately once per decade in the post-regulation period (Roberts, 2003). But recruitment may now be limited to larger, less frequent events due to greater hydrologic modification in recent years. Recruitment did result from the recent large flood events of 1983-1986, and 1995-1997, (Roberts, 2003) but willows dominate while cottonwood recruitment is spatially limited.

In order to maintain or re-establish woody riparian vegetation using a process-based restoration approach, managed flows need to mimic natural hydrographs in the following key ways (Stillwater, 2007):

- High flow peaks, which should mimic to some degree the characteristics of peak flows associated with winter peak rain events in the unimpaired hydrograph are necessary to control vegetation encroachment by herbaceous and weedy species and prepare seedbeds prior to seedling recruitment flows in wet years (scouring or encroachment prevention flows) and seedbed preparation flows.
- High spring snow-melt peak flows with relatively gradual recession rates during wet years to moisten the seedbeds and induce seed germination on geomorphic surfaces suitable for long-term establishment (recruitment flows for seedling initiation).
- Summer and fall base flows are needed to ensure that new seedling cohorts and older cohorts of saplings and mature trees have adequate soil moisture for summer growth and survival during the annual dry season (seedling establishment and maintenance flows).

In regulated rivers it may also be necessary to limit unnaturally high summer flows. Summer base flows higher than spring flows may give a competitive advantage to non-native species that reproduce by seed during the summer months. Establishment of non-natives could impede later recruitment of natives such as cottonwood (cite).

5.2.4 Site Preparation

Large flows scour away herbaceous plants and/or deposit fine sediments on floodplains, preparing new seed beds for pioneer riparian species (Mahoney and Rood 1998). The magnitude of flows necessary to scour or deposit seed beds is presumably much larger then the amount of water necessary to inundate these sites. For this analysis, we assume that flows sufficient to mobilize the bed (80-100k cfs on the Sacramento and 35,000-50,000 on the Feather) are sufficient and that seedling establishment flows will only occur in wetter years after bed mobilization generally occurs.

5.2.5 Seedling establishment:

In order to assure long-term survival, seedlings must become established in a zone that is high enough on the bars and banks to avoid scour from peak flows, but low enough to avoid desiccation during low flows in summer and fall. Rood and Mahoney (2000) developed a recruitment box model that placed this zone at 2.5 to 4 feet above mean low (MLW) water for the St. Mary River in Alberta Canada. Roberts (2003) calibrated the recruitment box model on the Sacramento placing the recruitment zone at 3-6 feet above MLW and developed a stage discharge relationship at three representative sites to determine that recruitment zone is inundated at flows between 23,000 and 30,000 cfs. Roberts recruitment zone, however, is based on the artificially high summer flows in the Sacramento River. Under natural summer flow conditions the recruitment zone, and flows necessary to inundate it, may be somewhat lower.

Little to no information exists regarding seedling establishment elevation for the Feather River. Furthermore, it is difficult to identify a suitable recruitment zone at some distance from the mean low water, because mean low water levels in the summer are two to three times higher then pre-dam, natural levels. The stage discharge relationship for the Feather River at Nicolaus combined with topographic maps indicate that the Feather River overflows its banks at Nicolaus at approximately 12,500 cfs. The banks further upstream are higher and can convey more flow before overtopping. Since cottonwoods generally become established on the banks and gravel bars of alluvial rivers, it is reasonable to assume that the recruitment zone is below the stage of the bankfull discharge. The seedling establishment flow on the Sacramento (23,000 – 30,000 cfs) is twenty seven to thirty seven percent of the bankfull discharge (Q1.5 to Q2) on the Sacramento. Assuming a similar proportional relationship on the Feather River, flows in the range of 9,500 to 18,000 would be suitable for seedling establishment. Analysis of historical flow data (section seven of this report) indicate that flows in this range were common during April and May when germination is most likely to occur.

Post-germination decline of river stage, which is presumed to control adjacent groundwater levels, should not exceed approximately one inch per day (Mahoney and Rood 1998, Busch et al. 1992). This is the rate at which seedling root growth (0.16–0.47 inches/day; Reichenbacher 1984, Horton et al. 1960) can maintain contact with the capillary fringe of a receding water table in a sandy substrate. Cottonwood root growth and seedling establishment rates are higher in these soils than in coarser textured soils, which are more porous (Kocsis et al. 1991). In reaches with gravelly substrates, slower draw-down rates are necessary to support seedling establishment.

Information necessary to design a gentle recession limb is limited. Stage discharge data from gauging stations may not be representative of Cotonwood recruitment sites, because they are generally sited at geomorphically stable and simple sites while cottonwood recruitment often occurs on complex and dynamic sites. Kondolf and Stillwater (Kondolf, 2007) measured stage discharge relationships at several representative gravel bars along the Sacramento River and determined that stage drops 0.1 meter (.34 feet) per 1000 cfs at flows ranging from 7,000 to 15,000 cfs, but cautioned against extrapolating this relationship to flows outside the observed range. Within this range, however, a discharge decline of 250 cfs per day would yield a stage decline of one inch per day.

To estimate a suitable recession rate flow schedule, we assumed that cottonwood seedlings would become established six feet above the mean low water and then calculated that it would take 72 days to drop river stage six feet at a rate of one inch per day. On this basis, we recommend a 72 day recession period from the establishment flow to the summer base flow. The actual recession flow required may vary substantially depending where seedlings become established relative to the mean summer flows.

5.2.6 Recruitment stage:

After the second year, growth rates level. Despite extensive root development during this stage, cottonwoods are still somewhat susceptible to drought stress. Yearly flows must be sufficient to maintain groundwater levels within 10 to 20 feet of ground surface elevations (JSA and MEI 2002). Groundwater extraction and reduced flows can reduce groundwater levels and induce drought stress in cottonwood saplings (Jones & Stokes 1998. Acute draw down and corresponding drought stress is primarily a problem in arid river ecosystems and will probably not be a problem on the Sacramento River where summer flows are artificially high.

5.3 Chinook Flow Requirements

Adult Upstream Migration

If salmon migration is motivated by major storms, early freshets or pulses after the first rain, and most of the large flows from storm events are trapped behind dams, reservoir operators can simulate pulse events by releasing water from the reservoir. However, "There is [a] concern that pulse flow releases in mid October to attract salmon may cause the fish to enter the rivers earlier than normal, which may expose them to high water temperatures when the pulse flows cease." (CMARP). Therefore, if flows are increased during this mid-fall period, it is important to continue to maintain adequate flows for migrating adults and subsequent spawning.

Spawning

In order to provide quality areas of spawning habitat, adequate flows need to be released from dams into the tributaries during the spawning period. Due to channel alteration from gravel mining, artificial gravel habitat construction and enhancement may be necessary. Over the long run, periodic high flows are necessary to mobilize gravels and flush-out fine sediments. However, large peak flow events that occur in channels that have been excessively incised and leveed cause excessive gravel mobilization, which can disrupt spawning and cause egg mortality (CMARP). Therefore, these flows should be released after mid-February so they reduce mortality to incubating salmon eggs (McBain and Trush, 2000). Increased flows may also be needed to decrease water temperatures in late October and early November to prompt earlier spawning, expand the area with suitable temperatures for spawning and incubation, to increase egg viability, and to reduce the probability of superimposition of redds. If flows are increased during this mid-fall period, it is important to continue to maintain adequate flows for spawning and to prevent dewatering of redds.

Egg Development and Emergence

Dewatering of redds is a known mortality factor effecting development of alevins. (Becker et al., 1982, 1983 in Healey, 1991). Dewatering of redds can be minimized below dams by careful flow regulation.

Adequate base flows during the incubation and emergence period combined with periodic flushing flows outside the period should reduce the mortality factor of eggs and alevins. Instream flows, at or above spawning flows, should be maintained throughout the incubation and emergence period to avoid dewatering redds. Siltation and capping from fine sediments could be minimized with small reservoir releases timed to coincide with rainfall induced local run-off. These releases would help convey fine sediments out of the spawning reach.

Rearing and Outmigration

We hypothesize that increasing rearing habitat will improve growth rates and successful smolt outmgration and may also reduce mortality from diversions and predation, because larger fish are less vulnerable to these sources of mortality. Based on robust results from research in the Yolo Bypass, it appears providing seasonally inundated floodplain habitat is perhaps the best way to ensure adequate growth before outmigration to the Delta and Ocean. If nothing else, providing seasonally inundated floodplain habitat will provide better habitat for the young that migrate or are washed out of the gravel bedded reaches early. We describe the flow regimes necessary to create inundated floodplain in section 6.3 above.

In addition to inundated floodplain habitat, seasonally inundated off-channel habitats may also provide valuable rearing habitats for juvenile salmon. Kondolf and Stillwater (Kondolf, 2007) determined that secondary scour channels on gravel bars along the upper Sacramento River become inundated and connected to the mainstem at flows above 12,500 cfs. They also determined that these same secondary channels become disconnected and desiccated at flows below 8,500 cfs. To assist juvenile rearing, it may therefore be advantageous to maintain flows between 8,500 and 12,500 cfs or greater during winter and spring when fish are rearing. To prevent establishment of non-native, resident predator fish populations that thrive in shallow or warm water habitats, however, it may be beneficial to maintain flows below 8,500 cfs during the summer months. Preventing inundation and connectivity of the off-channel habitats during summer months could also reduce temperatures by significantly reducing wetted perimeter and surface area. Lower temperatures should favor native fish over exotic fish populations.

6. EVALUATION OF EXISTING AND HISTORIC FLOW REGIMES

To identify specific hydrograph component alterations between historical and current conditions which may limit the attainment of environmental objectives an analysis of existing and historical hydrologic patterns was conducted using daily flow data from USGS gages at multiple locations on the Sacramento and Feather Rivers. We used two approaches to compare existing and historical hydrologic patterns, a statistical approach similar to IHA whereby specific hydrograph components were graphed using box plots for different year types and a visual approach similar to HCA whereby median hydrographs for historical and current conditions were compared.

We evaluated pre- and post-project hydrology using statistical methods similar to IHA and HCA methods to generate hypotheses regarding the causal links between historical hydrograph components and ecological conditions relevant to our restoration objectives. The Index of Hydrologic Alteration (IHA) method (Richter et al. 1996) provides a statistical overview of how several important hydrologic attributes change between historical and regulated conditions. The Hydrograph Component Analysis (HCA) method developed by McBain and Trush provides a detailed graphical analysis of historical and existing hydrologic conditions. Instead of using a formal IHA and HCA analysis the fundamental principals of these methods were used to conduct an analysis based on first principles.

To conduct this analysis USGS daily discharge data was organized into water year types based on the Sacramento Four Rivers Index. The water year data was divided into pre project or post project data sets. The project id defined by the construction of a dam in the headwaters of the river under consideration. For the Sacramento River the project is Shasta Dam which was constructed in 1945. For the Feather River the project is defined by Oroville Reservoir which was constructed in 1968. Hydrograph components for each water year were compared for pre and post project periods using box plots. This statistical approach was coupled with a visual comparison of the pre and post project median flows hydrographs. The pre project period was further defined by the 25th and 75th percentile hydrographs. The 25th and 75th percentile captured the natural range of variability around the median hydrograph during the pre project period for each year type. When the current hydrograph was outside of this acceptable range of variability then a significant discrepancy between the historic and current flow regimes could be identified.

The hydrograph components that were considered for the statistical analysis were: 1) summer baseflow, 2) winter peaks, 3) winter baseflows and 4) spring peaks(Figure 5). A useful way to describe streamflow hydrology and relate it to geomorphic, riparian, and biological ecosystem components is by quantifying these hydrograph components. Kondolf et. al. 2000 described these four primary components of the annual hydrograph in the following way:

(1) Summer base flows extending from July through Spetember/October

(2) Large magnitude, short duration winter floods during December through April

(3) Sustained high winter base flows intermittent between high flow events

(4) Spring snowmelt flood and recession limb of long duration, but typically moderate magnitude

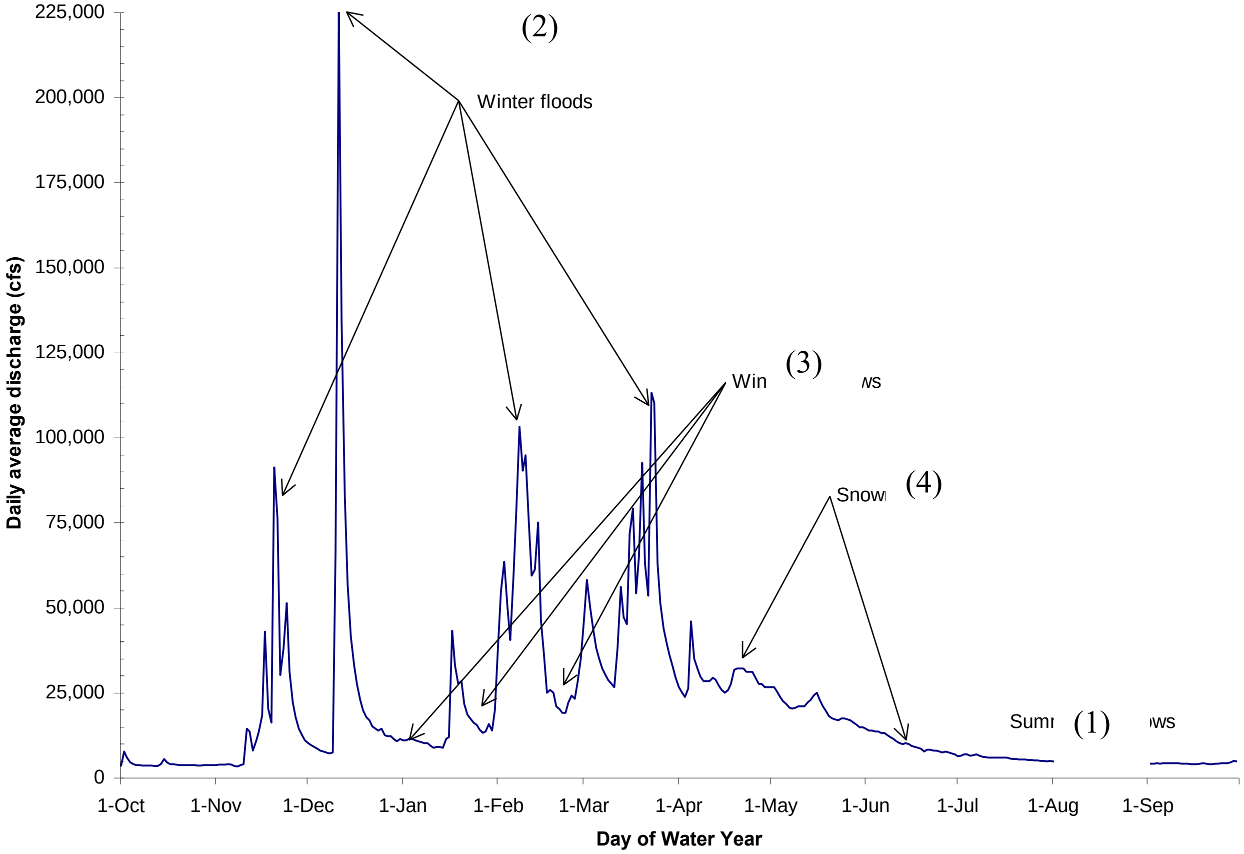
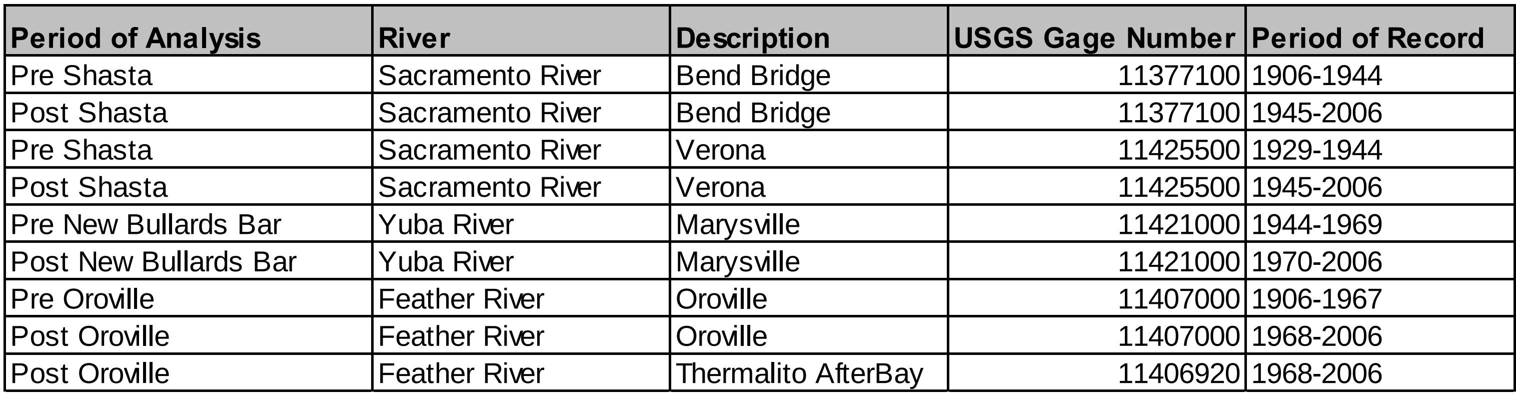


Figure 6.1: Sacramento River hydrograph components illustrated in the 1938 hydrograph for the Sacramento River above Bend Bridge, near Red Bluff gauging station. Modified from Kondolf et al. 2000.

a. Methods

Data Source

We analyzed hydrologic data for periods before and after dams were constructed on the Sacramento and Feather Rivers. Table 4 shows the gauges analyzed their period of record, and the pre and post-dam analysis periods. We divided data into five year types based on the Sacramento Basin Index: wet, above normal, below normal, dry, and critical.



Period of Analysis	River	Description	USGS Gage Number	Period of Record
Pre Shasta	Sacramento River	Bend Bridge	11377100	1906-1944
Post Shasta	Sacramento River	Bend Bridge	11377100	1945-2006
Pre Shasta	Sacramento River	Verona	11425500	1929-1944
Post Shasta	Sacramento River	Verona	11425500	1945-2006
Pre New Bullards Bar	Yuba River	Marysville	11421000	1944-1969
Post New Bullards Bar	Yuba River	Marysville	11421000	1970-2006
Pre Oroville	Feather River	Oroville	11407000	1906-1967
Post Oroville	Feather River	Oroville	11407000	1968-2006
Post Oroville	Feather River	Thermalito AfterBay	11406920	1968-2006

Table 6.1: USGS gauges used for hydrologic analysis, the period of analysis, location, description and the period of record.

Hydrographs

For each year type we compared post-dam median flows to pre-dam median flows. Median flows bounded by the 25th and 75th percentiles represent the natural range of variability during the pre-dam period for each water year type. Hydrographs provide a visual tool to identify portions of the current hydrograph that are outside of the historic range of variability. When the current hydrograph is outside of the natural range of variability we would expect the greatest potential loss of environmental flow benefits.

Box Plots

Box plots were used to statistically compare hydrograph components including summer baseflows, winter floods, winter baseflows, and spring peak flows. The lower edge of the boxes represent the 25th percentile and the upper end represents the 75th percentile, with the whiskers at the maximum and minimum values. The various components of the hydrograph were computed as follows.

- **Summer baseflows** were computed as average August discharge. Summer baseflows begin following the spring snowmelt recession in July and August and last through autumn when the first rainfall events occur.
- **Winter floods** were computed as the maximum daily average discharge over the course of the entire water year.
- **Winter baseflows** were computed as the median flow for February and March.
- **Spring peak flows** were computed as peak flows in April and June.

Flood Frequency Analysis

We conducted the food frequency analysis for a range of reoccurrence intervals for pre and post project periods using the peak instantaneous flow records at USGS. The flood frequency analysis enables further quantification of storm events and their geomorphic potential.

b. Results

The analysis utilized 100 years of daily flow data from the Bend Bridge gage near Red Bluff on the Sacramento River (11377100). This gage was selected for the analysis because it has a long period of record 1906-2006, and best characterizes flow conditions where salmon concentrate. The Bend Bridge gage is at the upstream end of what is considered the most valuable habitat in the Sacramento River. However, flows at Bend Bridge are not fully representative of downstream conditions, particularly in the irrigation season because irrigation diversions operate downstream. Four major diversions are listed below:

- The Glenn-Colusa Irrigation District (GCID) diversion, located just upstream of Hamilton City at RM 206, began diverting summer flows for irrigation around the turn of the century, and has a diversion capacity of about 3,000 cfs.
- The Anderson-Cottonwood Irrigation District (ACID) diversion, located on the north side of the City of Redding downstream of Shasta Dam, began diverting for irrigation during the summer months, around 1917.
- The Red Bluff diversion and Tehama-Colusa Canal at Red Bluff was built in 1964, and diverts during the summer months for irrigation.
- The Trinity River Division of the Central Valley Project was completed in 1963, and typically diverted over 1,000,000 acre-ft/yr of Trinity River flows into the Sacramento River basin just below Shasta Dam between 1963 and 2000. Due to new flow requirements for the Trinity River, substantially less flow is now diverted into the Sacramento River.

The hydrograph at Bend Bridge reflects operations at Shasta Reservoir in timing and magnitude, but it is only by looking at the hydrograph from a downstream gage that we can evaluate the impacts of diversions operations and the degree of hydrograph recovery from tributary inputs. It is for this reason that we used the eighty year record, from 1926-2006) daily discharge data at the USGS gage at Verona (11425500). Major tributary inputs to the Sacramento below Bend Bridge include Mill Creek, Deer Creek and the Feather River. The Feather River flow regime exhibits similar characteristics to the Sacarmento below Red Buff because of the operation of Oroville Dam. The major tributary to the Feather is the Yuba River which also displays similar characteristics due to the operation of Bullards Bar. For this reason a hydrograph comparison for the Feather (11407000, 11406920) and Yuba River (11421000) was also conducted.

5.2.1 Sacramento River at Bend Bridge

Hydrologic Changes
The hydrographs and box plots for pre and post Shasta at Bend Bridge (Figures 6 and 7) illustrate significant differences in all hydrograph components.

- Summer base flows are significantly higher post Shasta for all water year types. The average summer base flow pre-Shasta was 3,000-4,000 cfs which is significantly less than the current average of 10,000-12,000 cfs. These artificially high summer flows are driven by summer water supply demands for agriculture and power.

- Spring peak flow events are significantly reduced in the post Shasta era for below normal, above normal and wet year types and there is a truncated spring and early summer recession limb, particularly in wet years. The reduction in spring peak flows hampers cottonwood recruitment, seed establishment and germination.

- Winter peak flows are significantly reduced in the post Shasta era. The magnitude and duration of winter peak flows are responsible for channel forming flows. Channel forming flows effect cottonwood recruitment and off channel habitat formation critical to Chinook Salmon rearing and survival.

- In addition to significantly altered hydrograph components there is also a general decline in hydrologic variability in the post Shasta era.

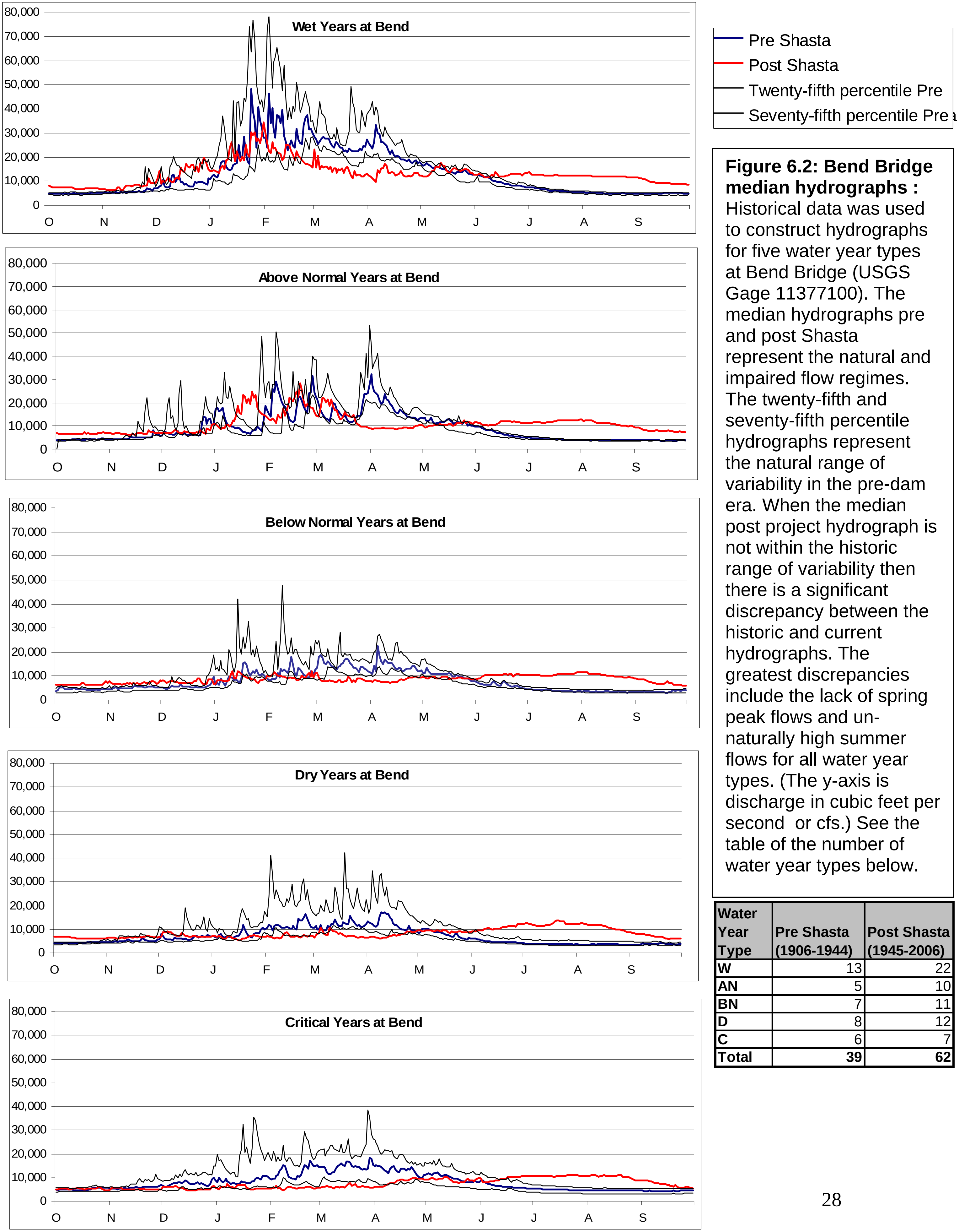


Figure 6.2: Bend Bridge median hydrographs : Historical data was used to construct hydrographs for five water year types at Bend Bridge (USGS Gage 11377100). The median hydrographs pre and post Shasta represent the natural and impaired flow regimes. The twenty-fifth and seventy-fifth percentile hydrographs represent the natural range of variability in the pre-dam era. When the median post project hydrograph is not within the historic range of variability then there is a significant discrepancy between the historic and current hydrographs. The greatest discrepancies include the lack of spring peak flows and un-naturally high summer flows for all water year types. (The y-axis is discharge in cubic feet per second or cfs.) See the table of the number of water year types below.

Water Year Type	Pre Shasta (1906-1944)	Post Shasta (1945-2006)
W	13	22
AN	5	10
BN	7	11
D	8	12
C	6	7
Total	**39**	**62**

Figure 6.3: Sacramento River Box Plots at Bend Bridge. Box plots display the median and the range of variability for each hydrograph component. Summer baseflows are represented by the average August discharge for each water year type. Winter floods are represented by the maximum daily average discharge for each water year type. Winter base flows are represented by the median discharge in February and March for each water year type. Spring peak flows are represented by peak average daily discharge value in April-June for each water year type. The top of the box plot is the 75th percentile and the bottom of the box is the 25th percentile. The 25th percentile means that 75% of the data is above this point. The wiskers represent the maximum and minimum values. The dark line inside the box is the median value, or 50th percentile. When the boxes do not over lap then there is a very highly significant difference between the data sets.

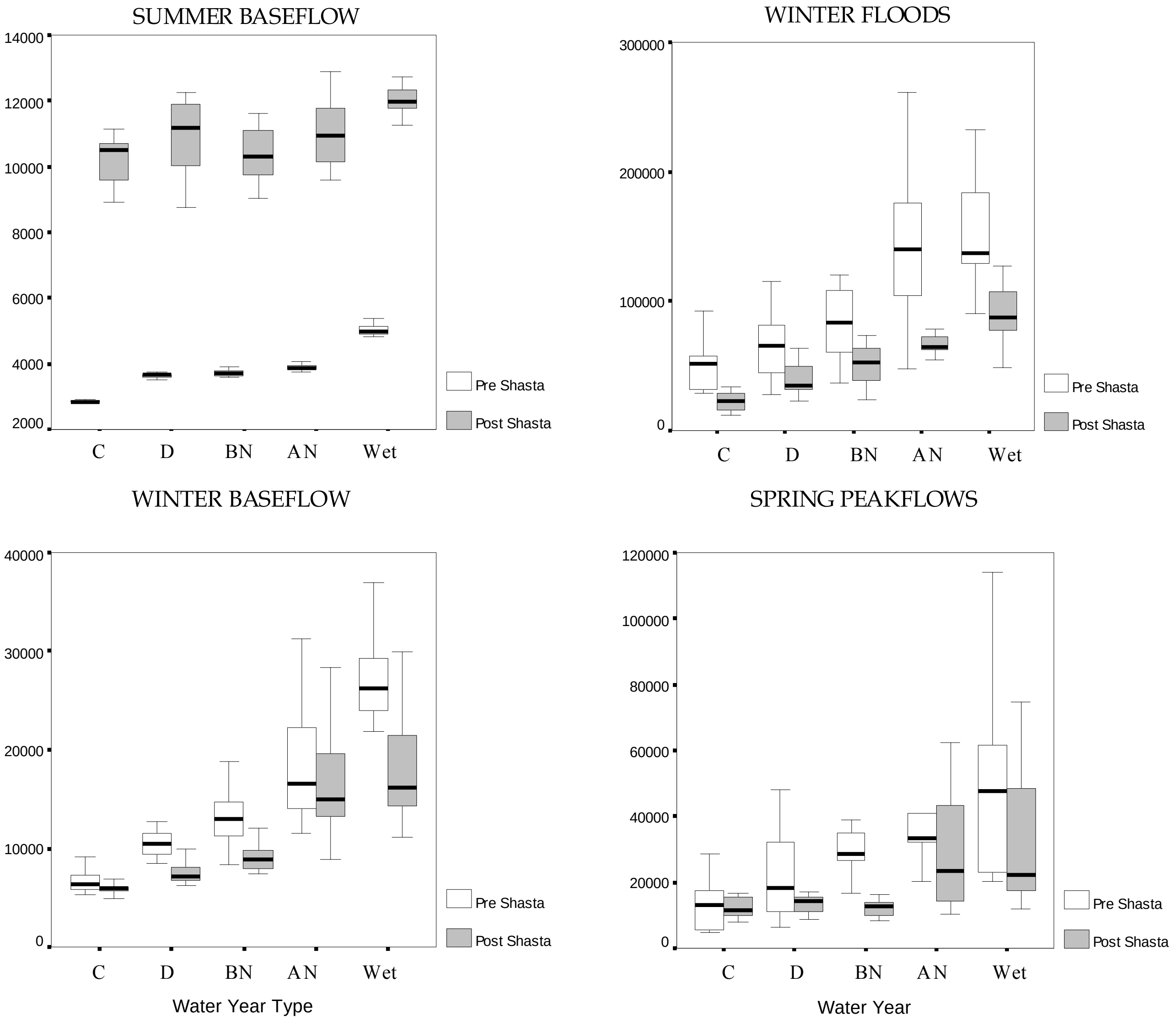


Figure 6.4: Flood frequency analysis at Bend Bridge Pre and Post-Shasta. The flood frequency analysis displays the magnitude of flows expected to occur in a 1.5, 2, 2.5, 5, 10, 20….year flood. The two year flood event in the pre Shasta era is ~100,000 cfs. Bed mobility is expected at the 1.5 year flood (Q1.5) or 82,795cfs.

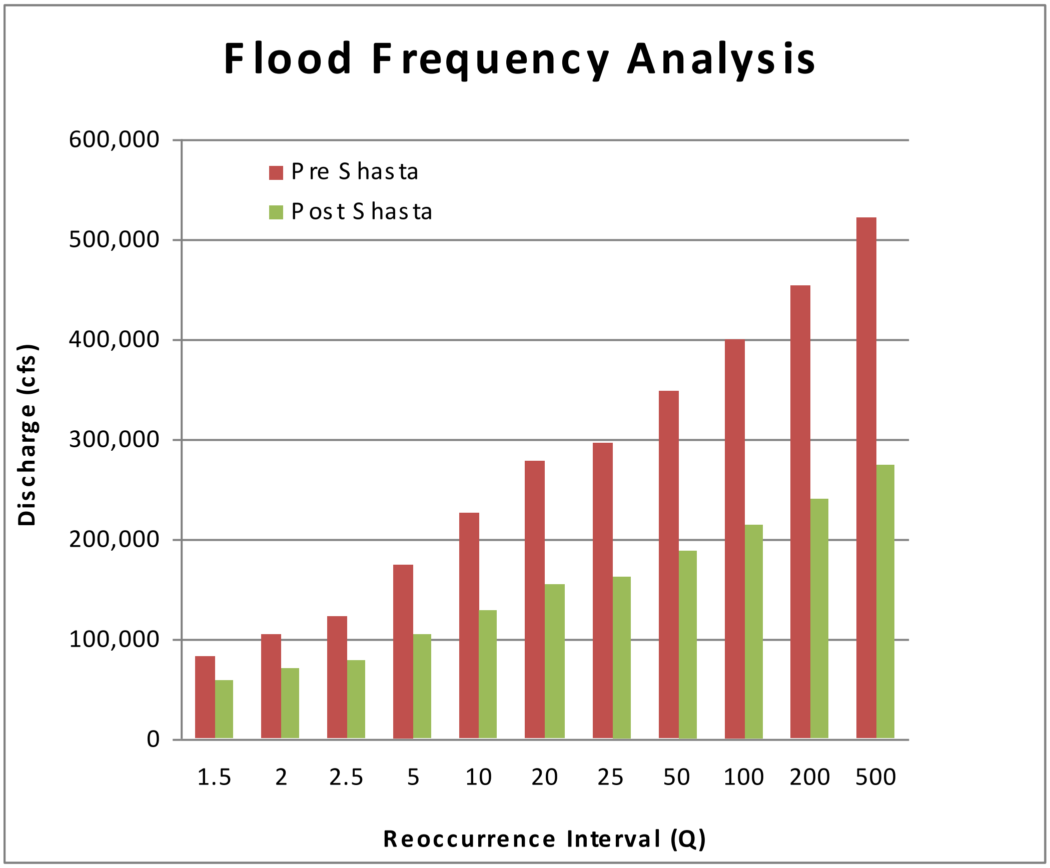


Table 6.2: Sacramento River Flood Frequency

Recurrence Interval (years)	Post 1939 (cfs)	Pre 1939 (cfs)
1.5	65,000	87,000
2	78,000	105,000
2.5	87,000	120,000
5	120,000	160,000
10	153,000	225,000
20	160,000	285,000
50	190,000	350,000
100	210,000	400,000

Table 6.3: Summary of Geomorphic Flow Thresholds				
Sacramento River	**Pre-Dam ($Q_{1.5}$)**	**Bed Mobility ($Q_{1.5}$)**	**Channel Scour and Migration (Q_{10})**	**Floodplain Inundation (Q_{1})**
Flows at Bend	82,795	82,795	226,476	52,087

6.2.1 Feather and Yuba Rivers

Introduction

Oroville Dam and Reservoir on the Feather River were completed in 1968 and have a storage capacity of 3.5 million acre feet (maf). It is managed for water supply, hydropower, and flood control. The average annual yield of the upstream Feather River basin at Oroville is about 4.2 maf. Due to several diversions in the upper watershed, average annual inflow into Oroville Reservoir is approximately 4.0 maf, but varies annually depending on precipitation. From 1979 to 1999, annual inflows ranged from a minimum of 1.7 maf to as high as 10 maf . Most of the water released from the dam, except during flood spills, is routed through the Thermalito diversion pool and afterbay and therefore bypass a 7 mile stretch below the dam known as the low flow channel. A minimum flow of 700-800 cfs is released into the low flow channel to maintain habitat for salmonids.

We evaluated change in hydrology that resulted from construction and operation of Oroville Dam. We compared pre and post dam hydrology at the USGS gauge below Oroville. In order to account for the water in the post-dam period that is discharged into the Thermalito diversion pool and bypasses the Oroville gauge, we summed daily values from the Thermalito (11406920) and Oroville (11407000) gauges to calculate the average daily flow for the river below the low flow channel.

Minimum instream flows below Thermalito Afterbay range from 1,000 cfs in the late spring and summer to 1,200 -1,700 cfs during the fall winter months. Minimum flows for the low flow channel are between 700 and 800 cfs all year. Minimum flows are slightly higher during the fall and winter to provide flow for spawning and incubating salmonids. Minimum flows in the summer are necessary to maintain cool temperatures for over summering juveniles and adult salmonids.

Most irrigation releases are made directly into irrigation canals, so relatively little water is conveyed to irrigators via the Feather River channel. Most irrigation water is released from Oroville Reservoir into Thermolito Diversion Pool, Forebay, and Afterbay where it is subsequently diverted into irrigation canals. Thus, it is possible to substantially meet summer irrigation demands without conveying water through the Feather River Channel.

The Feather River is joined downstream by a major tributary, the Yuba River. The hydrology of the Yuba River was modified early in the 19th century, but the first big storage reservoir, Bullards Bar, was not constructed until 1968. As a result, the hydrology of both the Yuba and Feather River were substantially altered at the same time by large reservoirs constructed in the late 1960s.

Hydrologic Changes

The construction and operation of Oroville dam and reservoir have significantly altered the hydrograph of the Feather River downstream of Oroville. Figures 10 and 11 depict the hydrologic patterns during different year types before and after 1968 when Oroville

Dam was completed. Figure 12 and Table 6 show changes in peak flow magnitude and duration. The most significant changes to the hydrograph are:

- Very significant reductions in spring flows during all year types, particularly during April and May. Storage of spring run-off and snow melt behind Oroville Dam has virtually eliminated any spring flows above a base flow of approximately 2,000 cfs.
- Increases in summer flows by 150-200% in all year types during July, August, and September.
- Reduction in the frequency and magnitude of peak flows, such as Q1.5[2] or channel forming flow by an order of magnitude. Substantially less reduction in the magnitude of the 5 year recurrence interval event (Table 6)
- Reduction in the frequency of short duration fall and winter flow pulses.

These hydrograph modifications are a result of Oroville Reservoir's water supply, flood management, and hydropower operations. Oroville Reservoir captures high flows in the winter and spring for use during the summer months. Stored water is released to meet minimum instream flows, irrigation demand in the Feather River region between April 1 and October 31, generate hydropower primarily in the summer, and meet water quality and export water demands in the Delta. Large volumes of stored water are periodically released during the winter months to create reservoir space for flood management purposes.

Most of the increases in summer flow in the Feather River channel are the result of Oroville releases to meet water quality and export demands in the Delta. As a unit of the State Water Project, Oroville is specifically operated to meet water quality and export demands in the Delta. An analysis of pre-1995 and post 1995 hydrology shows that Feather River flows changed significantly after the 1995 Water Quality Control Plan tightened restrictions on the timing of Delta diversions. After implementation of the plan, spring flow in the Feather River has been further diminished while summer flow has been further increased.

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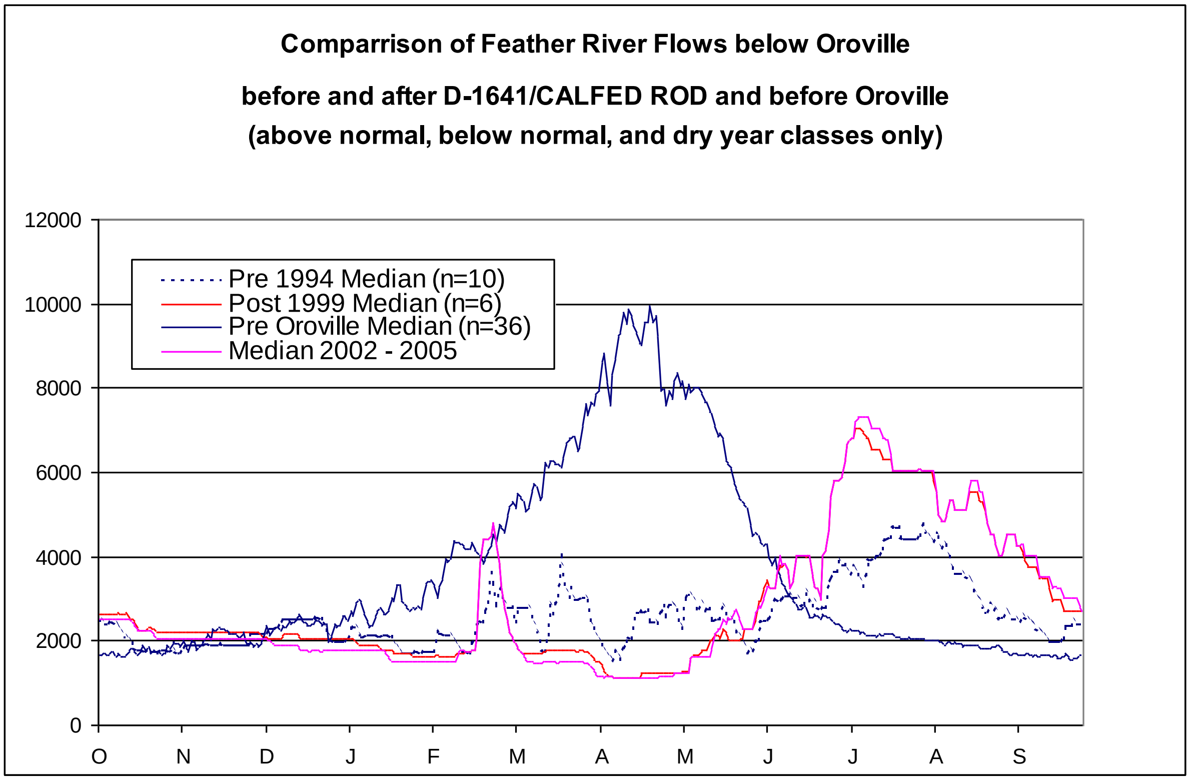
[2] The instantaneous peak annual flow with a recurrence interval of 1.5 years.

Figure 6.5: Influence of Sacramento-San Joaquin Delta Regulations on Feather River Hydrograph. The blue line of pre Oroville median flows represents the most natural hydrograph. In 1995 the Water Quality Control Plan tightened restrictions on the timing of Delta diversions. The pre 1994 hydrograph compared to the post 1999 illustrates how the hydrograph shifted spring flows to summer releases to meet Delta requirements.



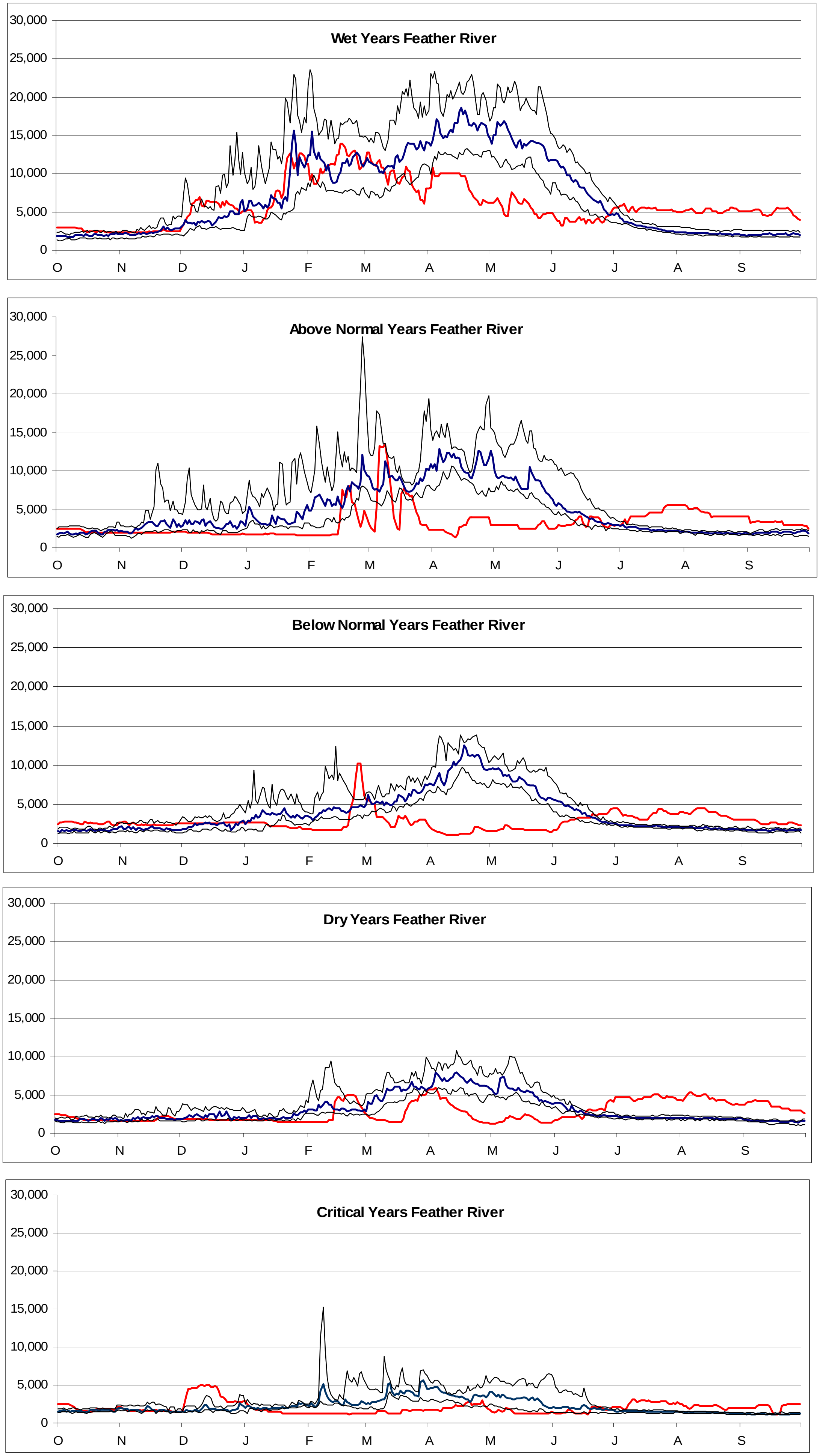


Figure 6.6: Feather River median hydrographs : Historical data was used to construct hydrographs for five water year types on the Feather River (USGS Gage11407000 and 11406920). The median hydrographs pre and post Oroville represent the natural and impaired flow regimes. The twenty-fifth and seventy-fifth percentile hydrographs represent the natural range of variability in the pre-dam era. When the median post project hydrograph is not within the historic range of variability then there is a significant discrepancy between the historic and current hydrographs. The greatest discrepancies include the lack of spring peak flows and un-naturally high summer flows for all water year types. (The y-axis is discharge in cubic feet per second or cfs.) The hydrographs post Oroville (1968-2006) are the sum of the Oroville (11407000) and Thermolito Afterbay gages (11406920). See the table of the number of water year types below.

Water Year Type	Pre Oroville (1906-1967)	Post Oroville (1968-2006)
W	20	15
AN	8	7
BN	14	4
D	14	6
C	6	7
Total	**62**	**39**

Figure 6.7: Feather River box plots for Oroville gauge. Box plots display the median and the range of variability for each hydrograph component. Summer baseflows are represented by the average August discharge for each water year type. Winter floods are represented by the maximum daily average discharge for each water year type. Winter base flows are represented by the median discharge in February and March for each water year type. Spring peak flows are represented by peak average daily discharge value in April-June for each water year type. The top of the box plot is the 75th percentile and the bottom of the box is the 25th percentile. The 25th percentile means that 75% of the data is above this point. The wiskers represent the maximum and minimum values. The dark line inside the box is the median value, or 50th percentile. When the boxes do not over lap then there is a very highly significant difference between the data sets.

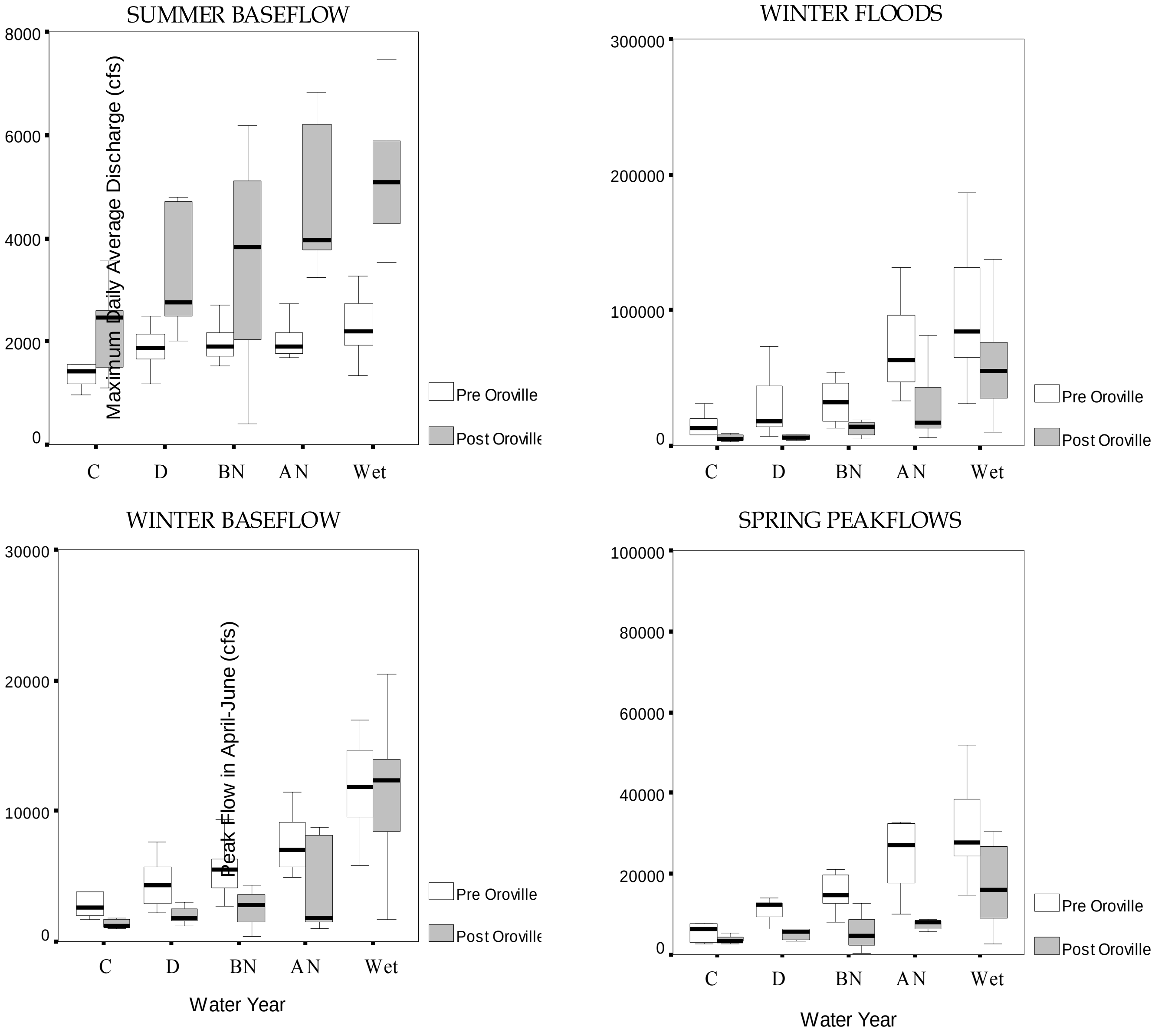


Figure 6.8: Flood Frequency Analysis for Feather River Flood frequency analysis at Bend Bridge Pre and Post-Shasta. The flood frequency analysis displays the magnitude of flows expected to occur in a 1.5, 2, 2.5, 5, 10, 20….year flood. The two year flood event in the pre Shasta era is ~50,000 cfs. Bed mobility is expected at the 1.5 year flood (Q1.5) or 33,224cfs.

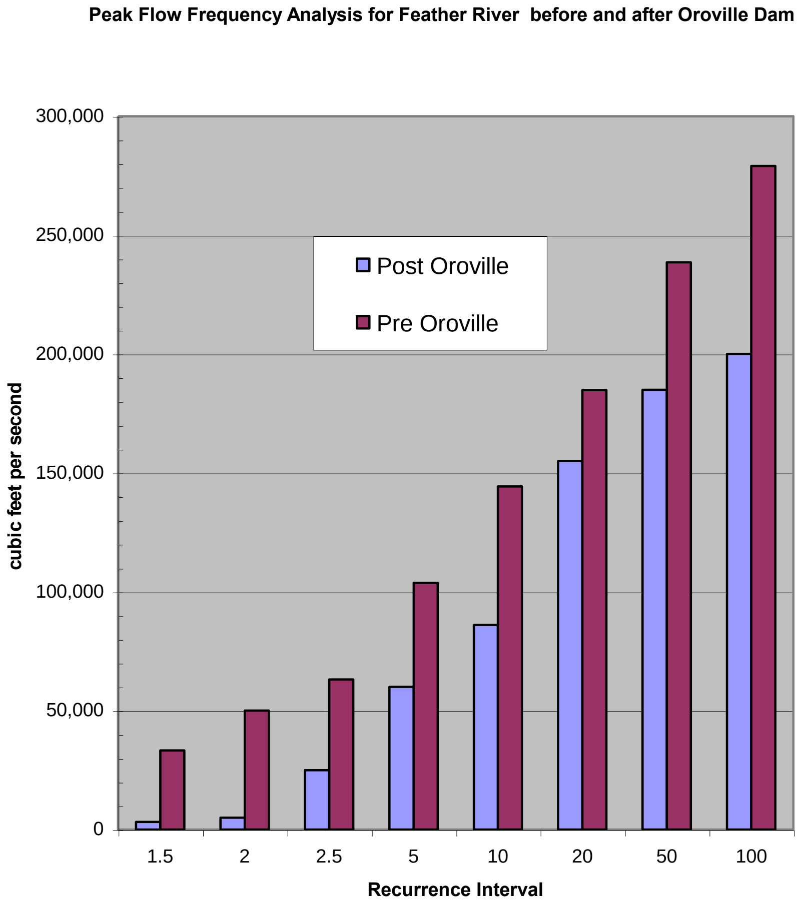


Table 6.4: Feather River Flood Frequency

Recurrence Interval (years)	Post 1968 (cfs)	Pre 1968 (cfs)
1.5	3,170	33,224
2	5,000	50,065
2.5	25,000	63,128
5	60,000	103,704
10	86,000	144,281
20	155,000	184,858
50	185,000	238,498
100	200,000	279,075

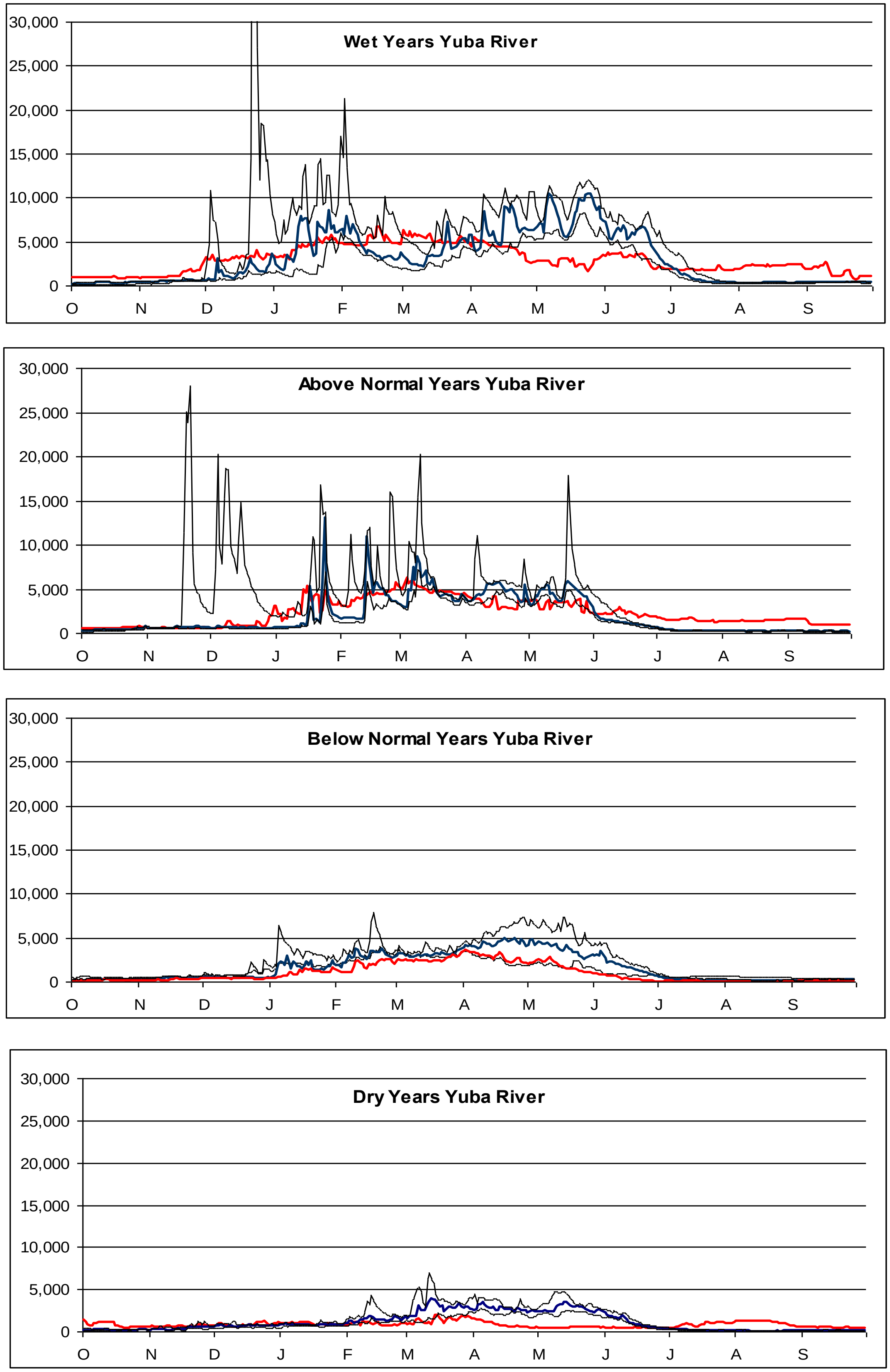


Figure 6.9: Yuba median hydrographs : Historical data was used to construct hydrographs for different water year types for the Yuba (USGS Gage 11421000). The median hydrographs pre and post New Bullards Bar represent the natural and impaired flow regimes. The twenty-fifth and seventy-fifth percentile hydrographs represent the natural range of variability in the pre-dam era. When the median post project hydrograph is not within the historic range of variability then there is a significant discrepancy between the historic and current hydrographs. The greatest discrepancies include the lack of spring peak flows and un-naturally high summer flows for all water year types. (The y-axis is discharge in cubic feet per second or cfs.)There is no median hydrograph for the Critical Year type because there were no critical years between 1944 and 1969. See the table of the number of water year types below.

Water Year Type	Pre New Bullards Bar (1944-1969)	Post New Bullards Bar (1970-2006)
W	7	13
AN	3	7
BN	8	3
D	7	6
C	0	7
Total	**25**	**36**

6.3 Sacramento River at Verona

Analysis of the Sacramento and Feather Rivers at gauges near the large dams only tells part of the story. The Verona gauge is downstream of the confluence of the Sacramento and Feather River, and measures run-off from numerous large tributaries not measured by the gauges at Oroville and Bend Bridge. Several of these tributaries do not have large storage reservoirs and thus continue to exhibit relatively natural hydrographs. Figure 14 shows the hydrographs from Mill and Deer Creek which are characterized by large, gently receding spring flows. As a group, these less regulated tributaries tend to dampen the effect of Shasta, Oroville, and New Bullards Bar, but only to a limited extent.

Figures 16 shows hydrologic patterns for four periods: before Shasta, after Shasta but before Oroville Dam, after Oroville Dam, and after the implementation of the 1995 water quality control plan that established stringent limits on the timing of water exports from the Delta. The hydrology from all four periods shows a clear and consistent trend: progressively less spring flow and continuously increasing summer time flows. The decrease in spring flows and increase in summer flows is particularly striking after 2000 when the water quality control plan was in full effect in the Delta. Due to stringent export restrictions in the spring, the state water project, which operates Oroville Reservoir and controls the Harvey O'Banks pumping plant in the Delta, has apparently shifted operations to minimize spring time releases from Shasta and favor summer time releases so that it can deliver water to the Delta when pumping restrictions are less severe.

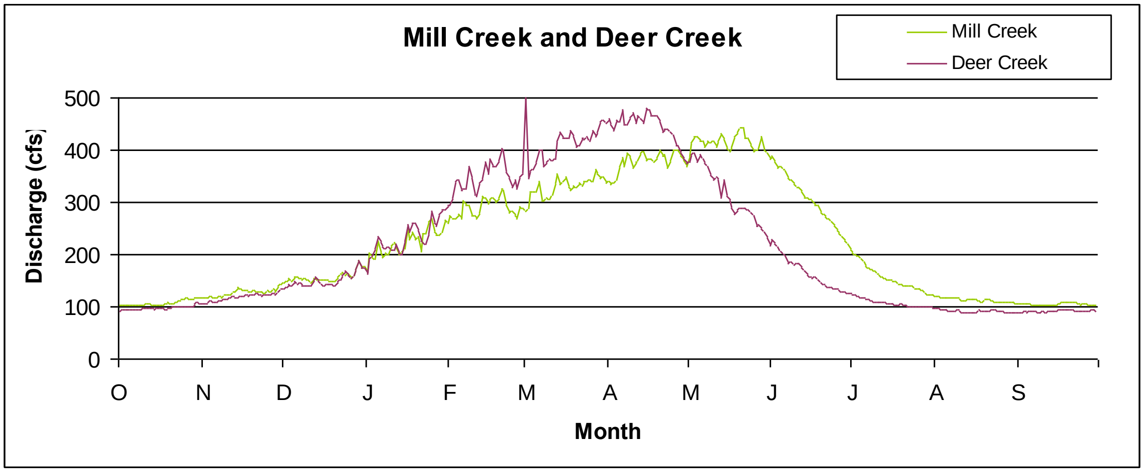


Figure 6.10: Median hydrographs for Mill and Deer Creek.

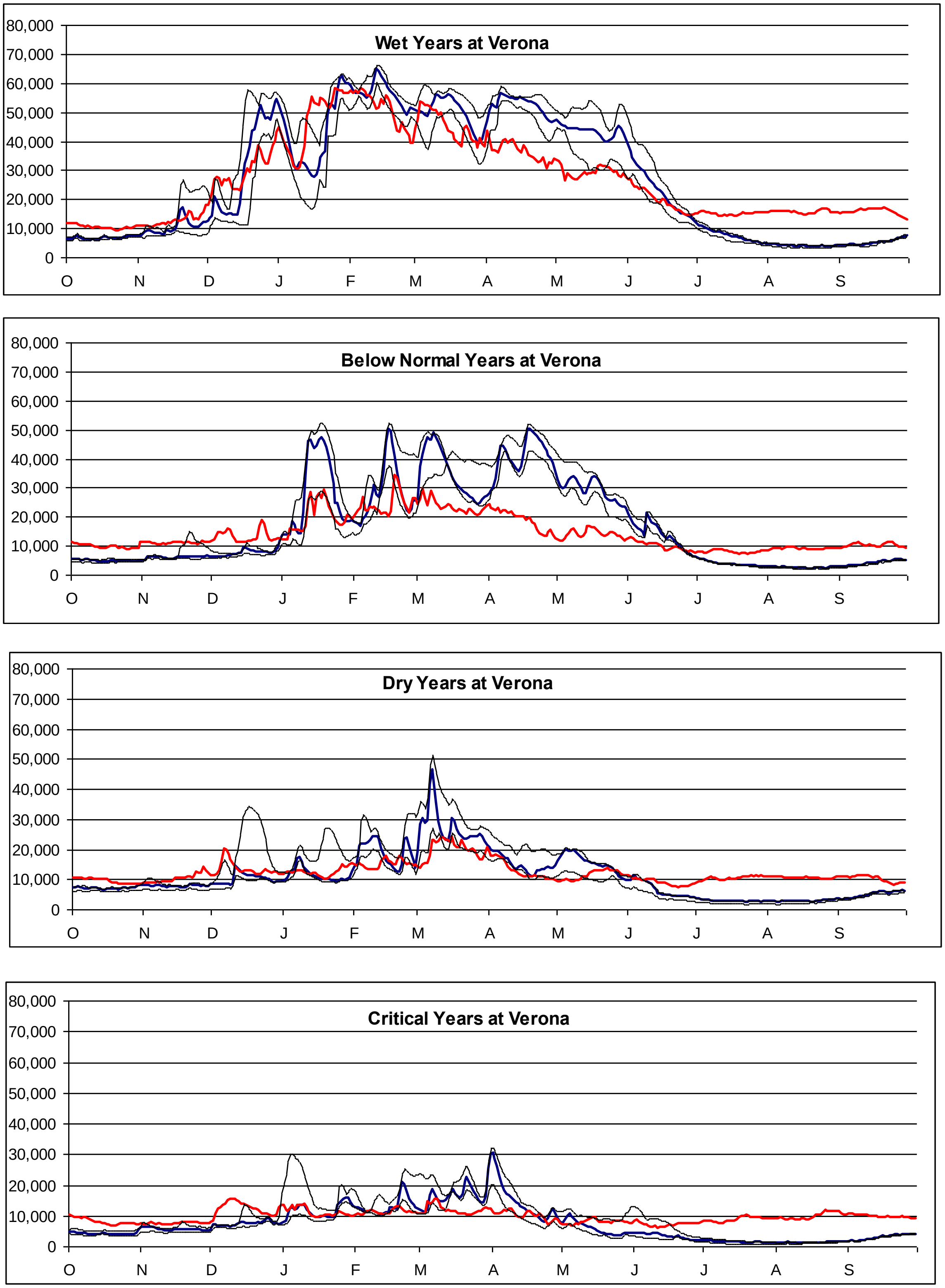


Figure 6.11: Verona median hydrographs : Historical data was used to construct hydrographs for different water year types at Verona (USGS Gage 11425500). The median hydrographs pre and post Shasta represent the natural and impaired flow regimes. The twenty-fifth and seventy-fifth percentile hydrographs represent the natural range of variability in the pre-dam era. When the median post project hydrograph is not within the historic range of variability then there is a significant discrepancy between the historic and current hydrographs. The greatest discrepancies include the lack of spring peak flows and un-naturally high summer flows for all water year types. (The y-axis is discharge in cubic feet per second or cfs.) There is no median hydrograph for an Above Normal Year type because there was only one year of this type between 1929 and 1944. See the table of the number of water year types below.

Water Year Type	Pre Shasta (1929-1944)	Post Shasta (1945-2006)
W	4	22
AN	1	10
BN	3	11
D	4	12
C	3	7
Total	15	62

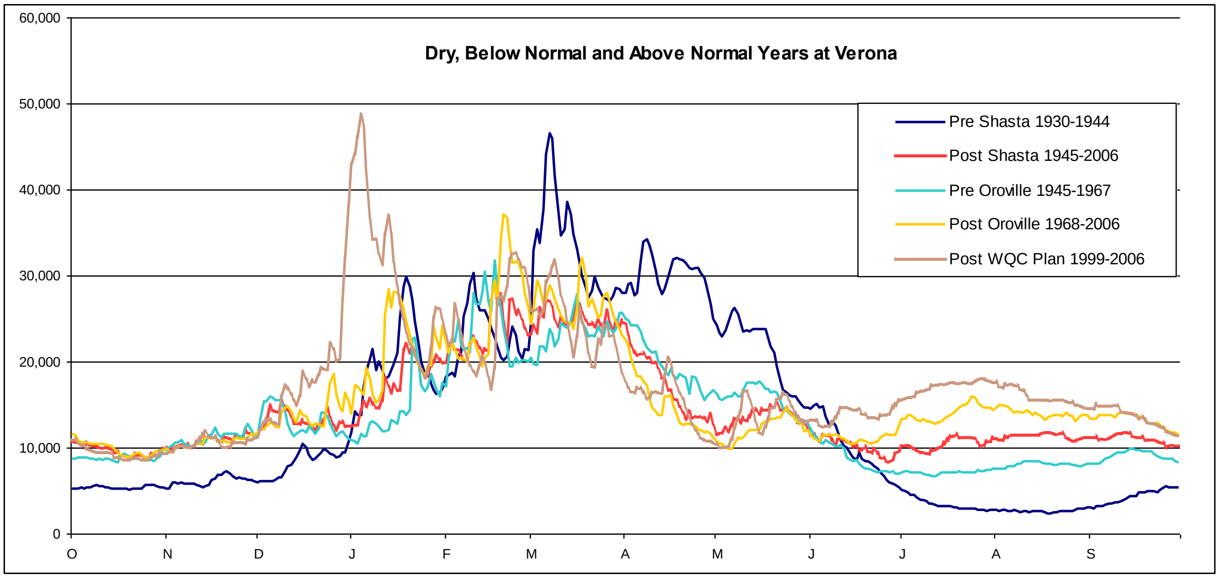


Figure 6.12: Median hydrographs for different time periods indicate a progression towards increased summer flows and decreased spring peaks. The increased regulation of the Sacramento and Feather Rivers with Shasta in 1945, Oroville in 1968 and the implementation of the Water Quality Control Plan in 1999 all had the effect of releasing increased flows during the summer when demands are high and as a consequence eliminated spring peak flows.

Summary of Results
From the hydrograph comparisons of current hydrographs to pre project, or natural hydrographs, a consistent trend immerges for all sites. This trend is the result of reservoir operations where by water is stored until periods of peak demand arise. In the Sacramento River basin peak demands occur in the summer months which means that reservoirs hold water through the spring, eliminating peak spring flows and augmenting summer base flows well above pre project levels. In this way reservoirs alter the timing and magnitude of the spring and summer hydrographs. In addition the presence large reservoirs in the headwaters dampen winter floods in all but the wettest of years. Loss of these geomorphic and riparian flows impacts riparian vegetation and Chinook Salmon habitat.

7.0 IDENTIFY OBVIOUS GAPS BETWEEN OBJECTIVES FLOW REQUIREMENTS AND EXISTING FLOWS

7.1 Gaps in Riparian Vegetation Objectives

Bed Mobilization

The frequency and size of large flows capable of mobilizing the bed have been reduced, but large flows occur in more than half of the years on the Sacramento River. The size of the Q1.5 has been reduced by twenty fiver percent. The pre-dam Q1.5 of 87,000 cfs now has a recurrence interval of every 2.5 years instead of every 1.5 years. While this is a significant reduction, it is a relatively small reduction in comparison to hydrologic alteration on other rivers such as the Feather or San Joaquin Rivers. The abundance of active riffles in the Sacramento River meander belt suggests that the river still periodically mobilizes its bed. Lack of bed mobility in the upper reach below Keswick Dam may be more a result of armoring due to coarse sediment trapping upstream then it is a result of reduced flows.

On the Feather River, the frequency and magnitude of peak flows has been reduced more substantially. The historical instantaneous Q1.5 – 2 has of 33,000 – 50,000 has been reduced by an order of magnitude to 3,000 – 5,000 cfs. The Q2.5, however, is 25,000 cfs. Under the post dam regime, several 4-5 years can pass without exceeding a bed mobilizing flow. This enable riparian vegetation to become established on gravel bars leading to long term stabilization and degradation of the channel.

Bed Scour

The frequency of very large, bed scouring events has been reduced substantially. The pre-dam Q5 of 160,000 cfs now has a twenty-year recurrence interval rather then a five-year recurrence interval. Similarly, the pre-dam ten-year flow now has a one hundred year recurrence interval. The physical processes and ecological function of these large events is not well understood. It is possible that smaller flows substantially scour the bed, rearrange the channel, and form new channel habitat. If so, the reduction in very large flows may not be as important. On the other hand, these very large events may be very important for creating and maintaining important habitats such as oxbow lakes and other off-channel habitats.

Bank Erosion and Channel Migration

We did not conduct an assessment of changes in stream power, but figure 5.2 illustrates that the occurrence of flows exceeding 15,000 or 20,000 cfs in dry, critical dry, and below normal years has been reduce substantially. Larson (2007) identified 15,000 cfs as the lower threshold for bank migration. Median flows frequently reached 15,000 cfs in these drier year types during the pre-dam period, but in the post-dam period median flows seldom rise above 10,000 cfs. During the wettest forty percent of years, wet and normal wet years, median flows frequently exceed 20,000 cfs and thus maintain some level of bank erosion and channel migration processes. Reduction in the frequency and duration of erosive events may have substantial impacts on the colonization and succession of riparian habitat over time. It definitely has habitat implications for bank swallow, a listed species that nests on recently eroded stream banks. Reduced bank erosion almost certainly lowers the suspended sediment levels and could therefore have significant impacts on instream fish habitat for juvenile salmon or Delta smelt that appear to prefer or concentrate in turbid waters (citation?). Although the reduction in the frequency or duration of bank erosion events may have significantly ecological impacts, it may be less important then the widespread presence of bank revetments along the Sacramento Rivers (Larson, 2007).

Inundated Floodplain and off-channel habitat during late winter and spring

The lack of prolonged flows of sufficient magnitude to inundate floodplain and off-channel habitats during the late winter and early spring months is perhaps the most significant ecological change to the Sacramento and Feather Rivers. Large, prolonged flows still occur in wet and normal wet years, but they are largely disconnected from the floodplains due to levees that prevent inundation of the vast historic floodplain of the lower Sacramento River. Large areas of the Sutter and Yolo Bypass become inundated in wet and normal wet years, but little or no floodplains become inundated for any length of time in the drier sixty percent of the years. This is a result of both levees and flow alteration, but flow alteration alone is sufficient to preclude floodplain inundation in the drier years.

Loss of shallow water habitats in secondary channels and floodplains not only reduces the amount of rearing habitat, it also may reduce foodweb productivity in the spring months when juvenile fish are rearing and moving downstream to the Delta. Increase connectivity between shallow water habitats and open water can substantially increase aquatic productivity in estuaries (Cloern, 2008).

Inundated off-channel habitat such as high flow channels can also provide rearing habitat for salmon (Peterson and Reid, 1984), but regulated spring flows are generally insufficient to inundate these habitats for prolonged periods (30-60) days. A recent study of these habitats in the Sacramento River determined that a large proportion of secondary channels between Red Bluff and Colusa become fully connected to the river at flows above 12,000 cfs (Kondolf, 2007). Regulated flows seldom exceed 10,000 cfs in the drier year types (dry and below normal) during late winter and spring when salmon are most likely to require spawning habitat. Even in normal wet years, median April flows are generally below 10,000 cfs.

7.2 Gaps in Riparian Vegetation Objectives

Peak spring flows are conspicuously absent under current conditions. On both the Sacramento and Feather River, median summer flows are significantly greater then median spring flows in all but wet years. As a result, any seeds that might germinate during the cottonwood seed release period in April and May are at risk of mortality from prolonged inundation throughout the summer months. If seeds to become established, they are less likely to grow deep roots during their first growing season due to high groundwater levels and therefore may be more vulnerable to desiccation mortality when water levels do drop.

In addition to the overall decapitation of the spring hydrograph, rapid flow declines during the spring months create a hostile environment for establishment of Fremont cottonwoods. Changes in the rate of the spring snowmelt recession are not obvious from the composite hydrographs depicted in figure 6 because they are of average spring flows over several years. The recession rate is more directly controlled by reservoir release operations in specific wet and above normal years. Our evaluation of hydrographs for individual years indicates that the recession rates are often characterized by abrupt changes in flow during the seed germination period on both the Sacramento and Feather rivers as illustrated in figures 6.1 and 6.2. Abrupt changes in reservoir releases during germination and initial seedling establishment period can limit recruitment by abruptly desiccating recently germinated seedlings before their roots reach the water table or by scouring and inundating newly established seedlings with high summer flows shortly after germination.

Even in wet years, median flows do not reach the documented threshold of 23,000 cfs on the Sacramento necessary to recruit riparian vegetation in a zone that is not vulnerable to subsequent channel scour. Similarly, the Feather River only reaches the assumed threshold of 8,000 -10,000 in median wet years. While it is true that the median numbers depicted in figure 6 obscure the variability that actually occurs in various years, figure 6 clearly illustrates how dramatically the critical spring and summer hydrograph has been altered in non-wet years. Even in wet years, the hydrographs are often not suitable due to the rapid fluctuation in flows (figures 6.1 and 6.2).

Figure 7.1: Annual hydrograph for Sacramento River at Bend Bridge illustrating abrupt flow decline in mid April during cottonwood germination period.

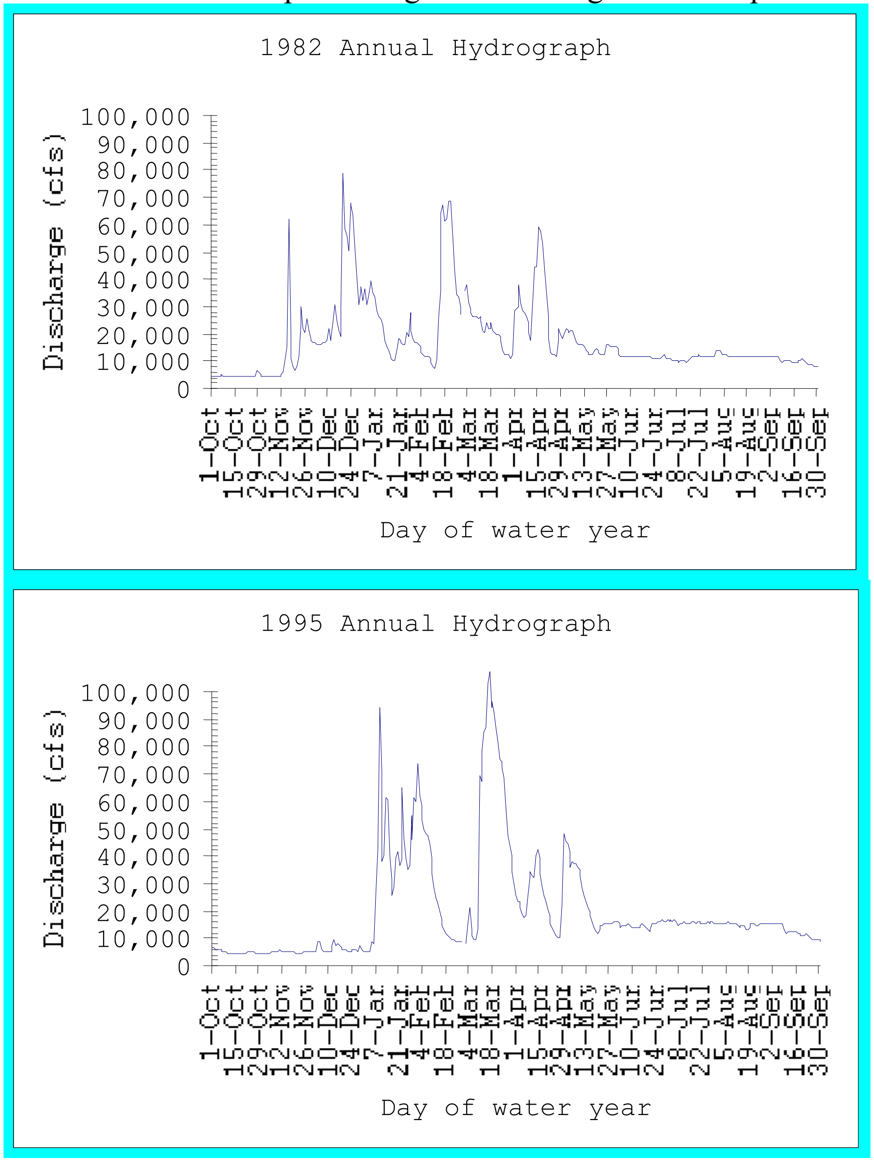
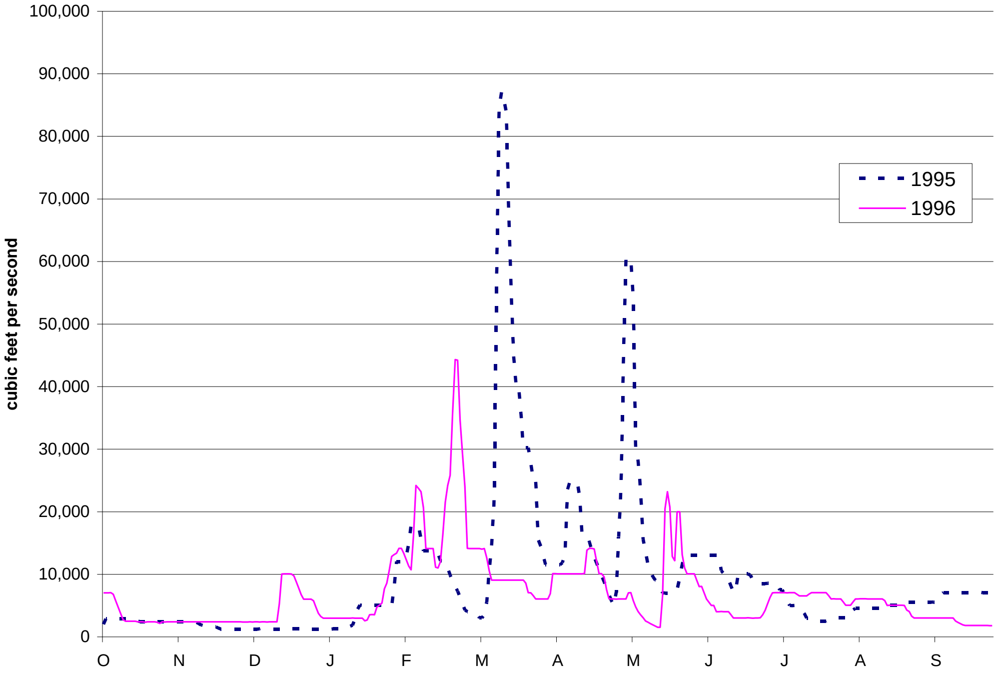


Figure 7.2: Annual hydrograph for Feather River at (sum of Oroville and Thermolito gauges) illustrating abrupt flow decline in mid April during cottonwood germination period.



7.3 Gaps in Chinook Salmon Objectives

Spring Pulse

Elimination of high winter and spring flows has substantially reduced the amount of rearing habitat on inundated floodplains and in off-channel habitats. A close examination of flow patterns indicate that later winter and early spring flows are increasingly the lowest flows of the entire year on both the upper Sacramento and Feather River. Under natural conditions, the highest prolonged flows of the year consistently occurred in the late winter and spring. This "spring rise" in flows inundated gravel bars, secondary channels and associated backwaters, and floodplains during the larger events.

Late winter and early spring flows at Bend Bridge on the Sacramento are about fifty to sixty five percent of what they were historically. A recent study of off-channel habitats on the upper Sacramento River (Kondolf and Stillwater, 2007) identified 12,500 cfs as an important threshold for inundating side channel habitats. On the Sacramento River, median spring flows at Bend Bridge seldom fell below 12,000 cfs between February and April prior to Shasta Dam. In the post dam era, median flows are consistently below 10,000 cfs in all but the wettest years. Meanwhile, summer flows which were historically below 5,000 cfs are now consistently above 10,000 cfs. The shift from spring to summer has become even more pronounced in recent years as dam operators have shifted operations to meet water quality and water supply demands for the Sacramento-San Joaquin Delta.

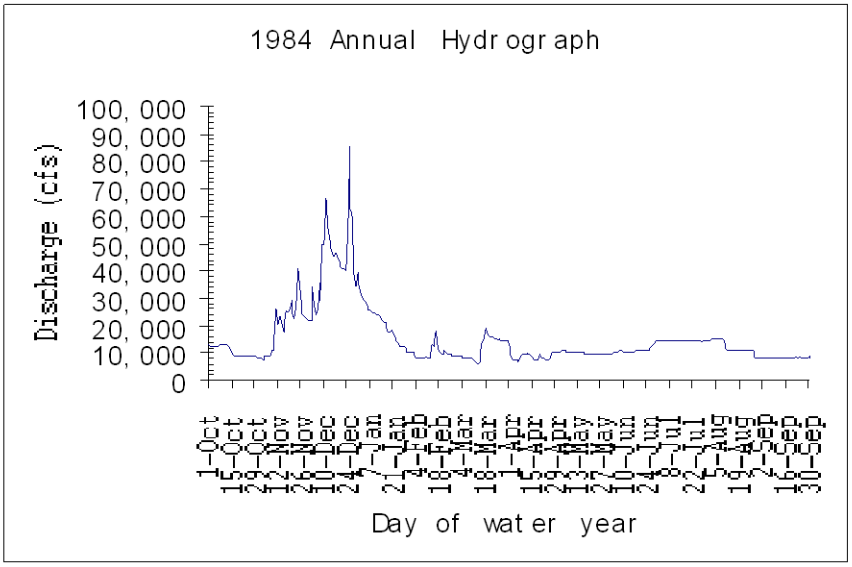
The pattern of reduced spring flows is even more pronounced on the Feather River where median spring flows are fifteen to thirty percent of what they were historically in most year types. The only exception is wet years when they are approximately fifty percent of the historical median. But even in these wetter years, the spring flows are characterized by abruptly fluctuating flood flows as illustrated in figure 6.2, rather then the prolonged spring pulse that characterized historic flows.

Fluctuating Flow Events

The median flow analysis presented in the previous chapter is not well suited for evaluating the frequency of abrupt flow changes, because the composite hydrographs depicted in figure 6 do not reveal individual flow events, which may harm salmon populations. The recent Nature Conservancy study of the Sacramento River (Stillwater, 2007, 2008 appendix F) hypothesized that abrupt increases or decreases in flows in the Sacramento may impact salmon and other species by scouring or dewatering reds, stranding fish, or eroding bank swallow nesting sites. Our cursory analysis of annual hydrographs, illustrated in figures x and xx, indicate that abrupt fluctuations in flow do occur in some years. The timing of these fluctuations may be a significant problem for fish in individual years. Large, rapid fluctuations in the winter or spring could strand juvenile salmon on floodplains or was juveniles downstream to poor habitat. Large reservoir releases in the fall, followed by declines to a significantly lower stage during the remainder of the winter, as illustrated in figure 6.3, could result in dewatering and stranding of redds. Large fall releases are usually limited to periods following very wet years when reservoir levels are high and need to be reduced prior to the rainy season for flood control purposes.

It is clear that large fluctuations in flow occurred under natural conditions on both the Feather and Sacramento Rivers. It is unclear how and whether individuals and populations of these salmon survived these events. Did very high flows that scoured the bed result in reproductive failure? How often did this occur? It is likely that today's regulated flow regime fluctuates in the present day riverine conditions is more likely to harm salmon then fluctuating flows under historical conditions. Under historical flow conditions, high peak flows are often followed by subsequent peaks that might enable stranded fish to reenter the river. More habitat complexity under historical conditions increased the probability that salmon could spawn or take refuge in areas safe from the potential negative effects of high flows. In today's environment, large peaks are often abruptly ended only to be followed by weeks of low flows. Levees and channelization have cut-off important refuge and foraging habitat that fish might have otherwise used during high flows.

Figure 7.3: 1984 annual hydrograph from the Sacramento illustrating high flow falls that could result in salmon redd stranding and reproductive failure.



Base Flows

Base flows in the Sacramento and Feather Rivers have been increased in most months except the spring, as previously discussed. Increased base flows during the summer and fall probably lower water temperatures and improve fish passage conditions. It is unclear whether unnaturally high base flows in the summer and fall have any deleterious impacts on fish such as harboring exotic species.

8 ENVIRONMENTAL FLOW REGIME RECOMENDATION

This chapter identifies flow recommendations for the Sacramento River based on the objectives and flow thresholds identified in chapters three and four, and the analyses of natural and regulated hydrology presented in chapters five and six.

Although this study identifies hypothetical restoration flow regimes for the Sacramento and Feather Rivers, we recognize that the most reliable method for developing a restoration flow regime is through a long-term adaptive management program. The hypothetical flow regime that we have developed and identified is imperfect, but it serves as a reasonable starting point for evaluating the feasibility of reoperating reservoirs without impacts on existing reservoir functions.

The assumptions and uncertainties associated with the hypothetical flow regime are as important as the flow regime itself. To cost effectively achieve restoration, managers will ultimately need to test these assumptions and address the uncertainties through a program of modeling, pilot flow studies, model calibration, and long-term restoration implementation. In the text below, we have explicitly identified some of these uncertainties so that they can be further evaluated.

8.1 Summary Recommendation

The key component of the environmental flow proposal for both the Sacramento and Feather Rivers is to restore higher flows during the late winter and spring. This period was once characterized by sustained, high flows. Under regulated conditions, however, spring flows are nearly half their historic volume and substantially below summer flows. We recommend restoring a stable spring base flow that is sufficient to inundate secondary channels, as well as, a spring pulse flow to inundated floodplains, particularly the Yolo and Sutter Bypasses.

A second key objective of the flow regime is to ensure adequate flows for the geomorphic and riparian processes that are necessary to sustain riverine and riparian habitat. We recommend short duration, high magnitude flows during the late winter to increase the frequency of hydrologic events that will mobilize the river bed or erode river banks. During late winter and early spring, we recommend prolonged duration moderately high flows to create inundated floodplain habitat for salmon. During the spring of wet and normal years, we recommend moderate duration, high flow evernts in wet and normal wet years to facilitate recruitment of Fremont cottonwoods and other riparian vegetation.

Restoring higher flows in the spring will necessarily reduce flows during other times of the year We propose reducing summer base flows to enhance spring flow, but realize that this could reduce suitable habitat for winter-run salmon during the summer months. We are not proposing any changes in the cold water pool management regime, which currently assures cold water releases from Shasta Reservoir. We recommend against diverting additional water away from the winter months, because we believe that existing winter flood events are necessary to create and maintain riverine and riparian habitat.

8.2 Sacramento River

Summary recommendations for Sacramento River base flows, key ecological flows, and a flow schedule are presented in tables 7.1 – 7.3. Illustrative flow recommendation hydrographs for each year type are presented in figure 7.2.

Table 8.1: Sacramento Environmental Flow Targets for Bend Bridge and Verona

	Critical	Dry	Below Normal	Above Normal	Wet	Location
Bed Mobilization		35,000	65,000	85,000	105,000	Bend
Floodplain Inundation			25,000	35,000	45,000	Verona
Riparian Establishment Flow				23,000	37,000	Bend
Bed Scour	No Recommendation					
Channel Migration						

Table 8.2: Sacramento River Base Flow Target Summary for Bend Bridge

	Critical	Dry	Normal Dry	Normal Wet	Wet
Fall base flow	5,250	5,250	5,250	5,250	5,250
Winter base flow	4,500	6,000	6,500	7,000	8,000
Spring base flow	10,000	12,000	12,500	14,000	14,000
Summer Base	8,000	8,000	8,000	8,000	8,000
Summer Base at Colusa	4,000	4,000	4,000	4,000	4,000

Table 8.3: General Timing and Duration of Sacramento Environmental Flow Targets

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Geomorphic				▨	🟨 2/15 -3/15	🟨	▨					
Floodplain Inundation					🟨 Only 45 Days	🟨	🟨					
Riparian Establishment Flow							🟨					
Riparian Recession Limb								🟨	🟨			
Spring Rise						🟨	🟨					
Fall Base Flow	🟨	🟨										🟨
Winter Base Flow			🟨	🟨	🟨							
Spring Base Flow						🟨	🟨	🟨				
Summer Base Flow									🟨	🟨	🟨	

8.2.1 Fall Base Flows

We propose stepping flows down from a stable summer base flow (see below) in late September in the upper river (between Keswick and Red Bluff). Under both natural and regulated conditions, flows in early fall are the lowest flows of the year. The primary purpose of lowering fall base flows closer to their historic levels is to economize on water and shift the saved water to the spring months when it is more important. The secondary purpose is to provide stable base flows for spring and fall-run spawning salmon and suitable rearing conditions for winter-run 5,500 cfs release from Keswick is about 1,000 – 1,500 cfs below existing fall base flows, but should be adequate for spawning habitat. The fall base flows must be stable to avoid dewatering or redds that may occur when flows are substantially dropped from the norm. Lower base flows in October could also potentially improve rearing habitat for winter run by creating slightly warmer fall water temperatures and thus an increased food supply.

Below Keswick	5,500
Below Red Bluff Diversion	5,250
Below GCID Diversion	5,000
Below Colusa	4,750

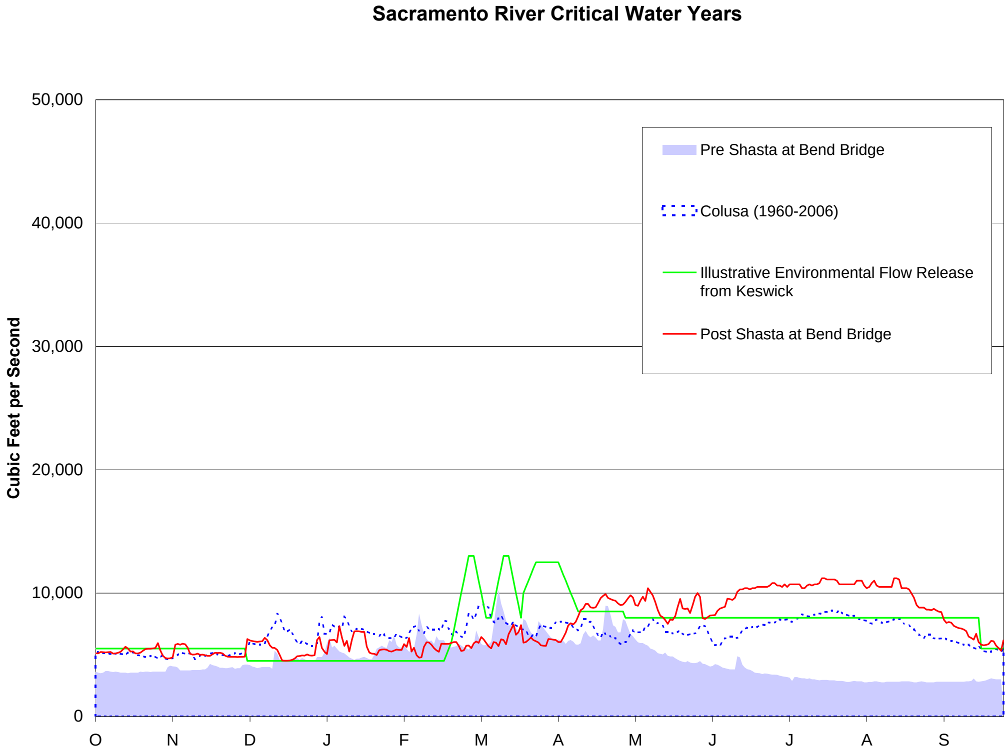
Key Uncertainties

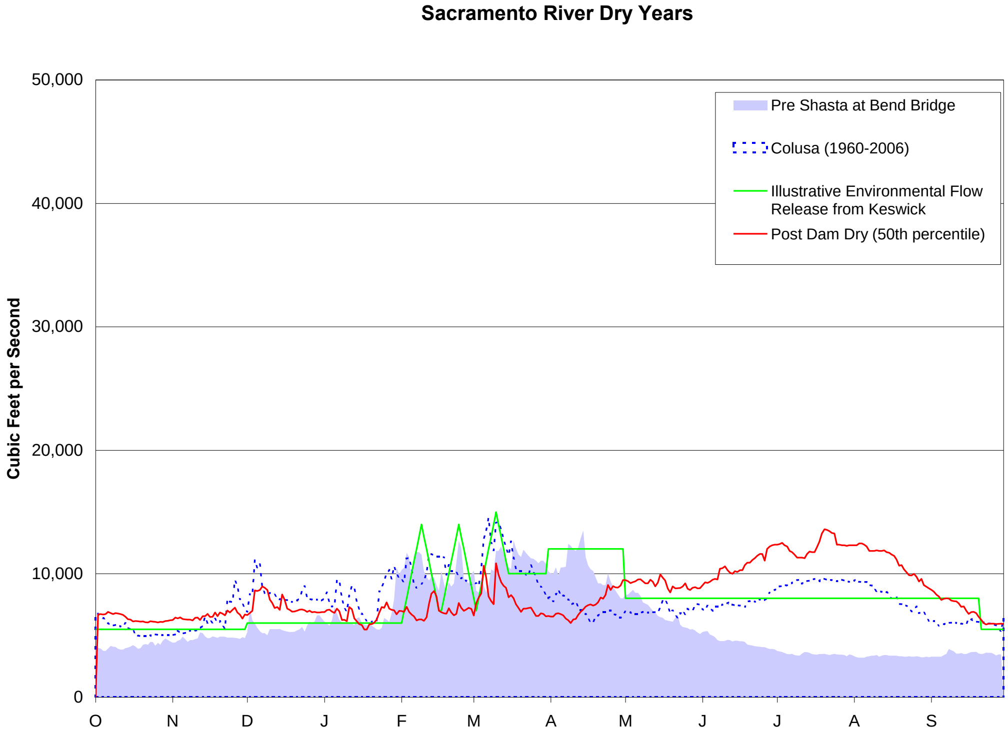
- Are proposed fall base flows sufficient for area of spawning habitat?
- Will lowering fall base flows provide warmer, slower velocity habitat for rearing winter run juveniles, and will this improve their growth and survival?
- Will reduce fall base flows cause adverse impacts in the Delta ecosystem?

8.2.2 Fall Pulse Flow

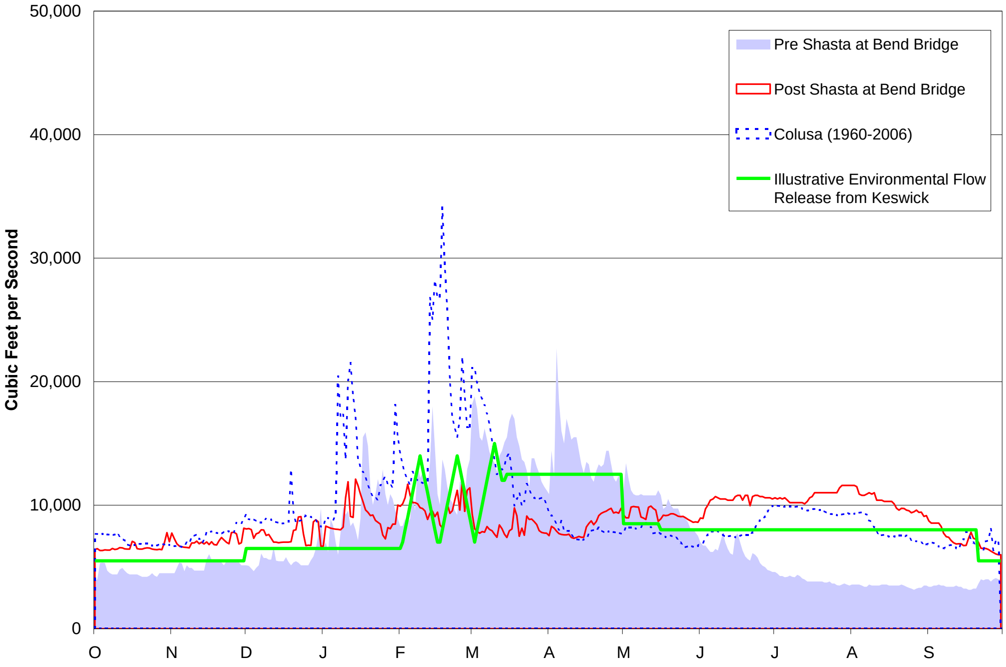
We considered a pulse flow to improve rearing conditions for juvenile salmon in the fall but did not include it in figure 7.2. The purpose of the fall pulse flow would be to improve food supply and rearing conditions for the winter run salmon and is loosely

Figure 8.2: Illustrative environmental hydrographs for five year types on the Sacramento River relative to existing regulated hydrograph and pre-Shasta hydrograph.

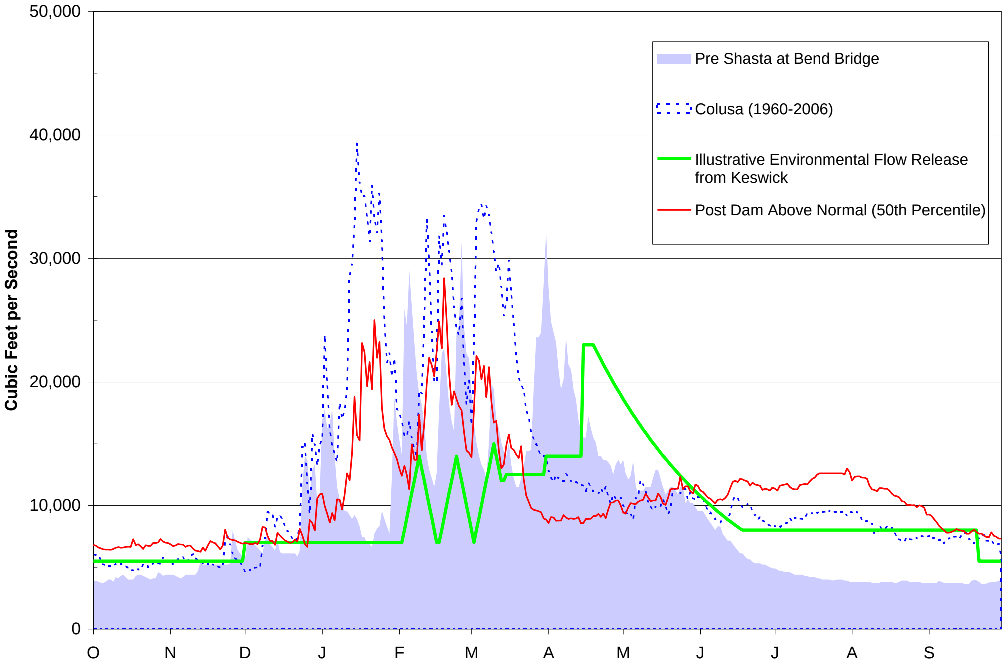


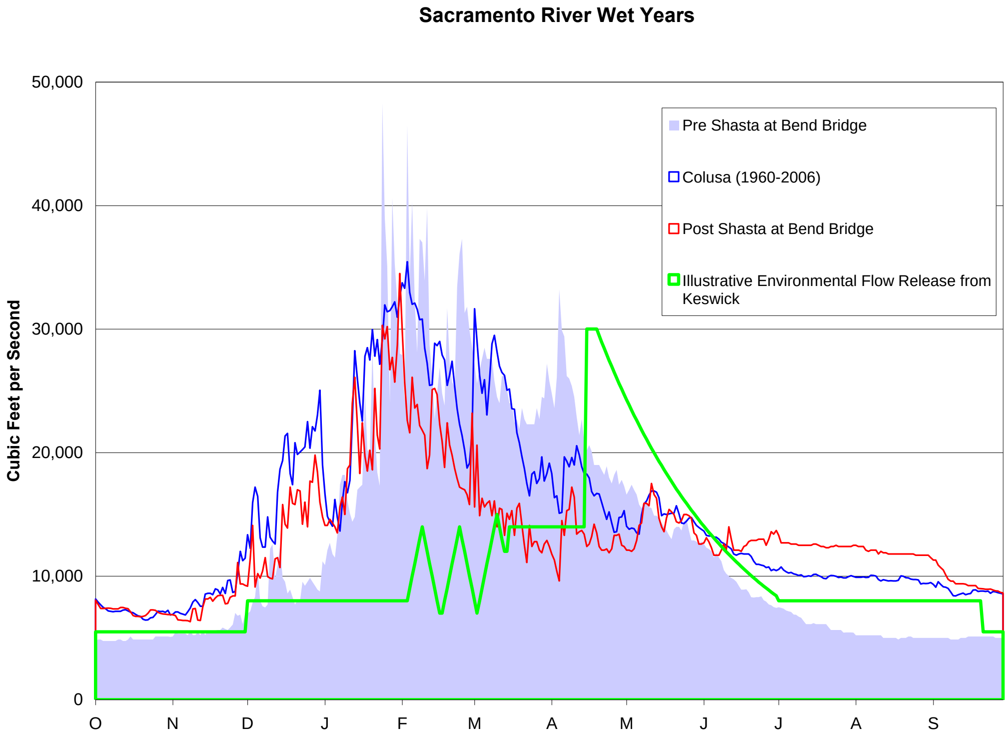


Sacramento River Below Normal Years



Sacramento River Above Normal Years

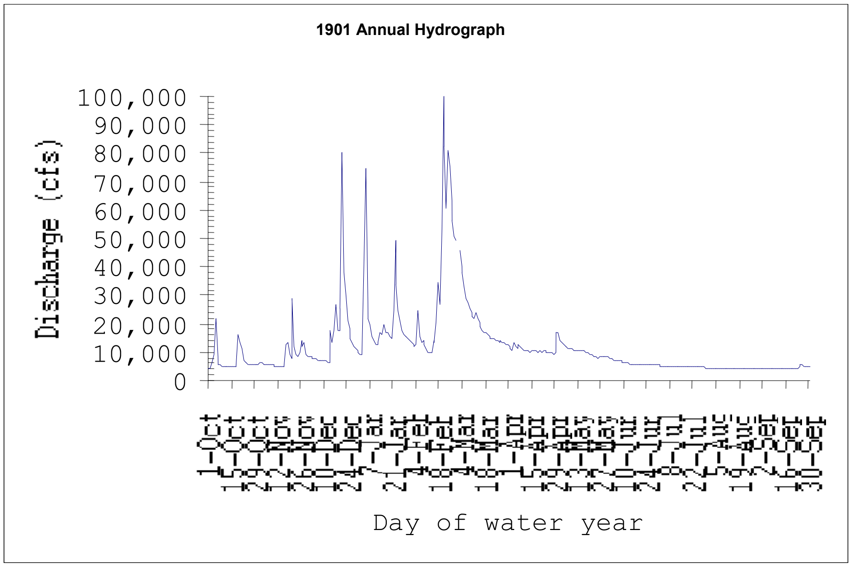



Sacramento River Wet Years
Cubic Feet per Second
50,000
40,000
30,000
20,000
10,000
0
O
N
D
J
F
M
A
M
J
J
A
S
Pre Shasta at Bend Bridge
Colusa (1960-2006)
Post Shasta at Bend Bridge
Illustrative Environmental Flow Release from Keswick

based on recommendations of the recently published Sacramento River Environmental Flows Report (Stillwater, 2007; ESSA Technologies, 2008). Rather then releasing a long duration rearing flow as proposed by Stillwater, it may be more economical to release two or three short duration pulses (3-5 days) of 12,000 cfs in late September and early October to inundate secondary channels and channel margins. The initial pulses would inundate the side channels and then be lowered to allow high residence times in the side channels. Each pulse would be followed by a subsequent pulse to flush food resources into the main channel and prevent fish stranding.

The main potential problem with a fall pulse flow would be to enable salmon, particularly spring run, to spawn on areas that would subsequently be dewatered. If the pulses are short enough, this problem may be limited. But the shorter the pulses will provide less potential for rearing habitat and food supply. Early fall pulse flows were rare under natural conditions, but they did occur occasionally as illustrated by the 1901 hydrograph (figure 7.1). Under regulated conditions, the winter run are confined to the mainstem river. The fall pulse, although largely unnatural, is designed to improve rearing conditions for them before cool winter months when food resources will presumably be less abundant.

Figure 8.1: 1901 hydrograph at Bend Bridge illustrating the rare, but natural occurrence of early fall pulse flows.



Key Uncertainties

- Will fall pulse flows for a few days result in dewatered reds once the pulse subsides?
- How long do secondary channel habitats need to be inundated in order to provide prolonged and substantial food supply benefits in the main channel?

8.2.3 Winter Base Flows

The purpose of the winter base flows is to provide stable conditions for incubating salmonids and reduce flashy regulated hydrology that can result when run-off from unregulated tributaries, primarily on the west side, is not modulated by less flashy natural hydrology from the larger, regulated watersheds. We recommend base flows of between 4,500 cfs in critical dry years and 8,000 cfs in wet years (table 7.4), which is similar to both existing regulated conditions and pre-dam historical conditions.

The winter base flows are a minimum base flow and are designed to occur in combination with unregulated run-off and flood control releases. Figure 7.2 shows the winter base flows as a straight line, but it is just a base flow that supports larger, unregulated peak flows. As a result, actual flows at Bend Bridge will be far more variable then depicted in figure 7.2.

Table 8.4: Winter base flow release from Keswick

	Critical	Dry	Normal Dry	Normal Wet	Wet
Winter base flow	4,500	6,000	6,500	7,000	8,000

Fairly substantial winter base flows combined with run-off events from less regulated tributaries will increase the frequency of inundation of channel margins and secondary channels that may serve as important rearing habitat.

8.2.4 Winter and Spring Peak Flows

The geomorphic flow targets discussed below may require additional releases from Shasta but are not explicitly included in figure 7.2 because they are short duration flow events that would be constructed upon unregulated run-off peaks. Smaller magnitude winter and spring peaks for fish rearing discussed below should be sufficient, particularly if reshaped, to achieve geomorphic targets below Red Bluff when combined with unregulated run-off.

Bed Mobilization

We recommend increasing the frequency of channel migration and bed mobilization flows during dry and below normal years for the reasons discussed in Appendix B. On the basis of thresholds discussed in chapter six, we recommend measures to achieve bed mobilization flows in most years (table 7.5). Based on the analysis of flow thresholds presented in chapter five, 35,000 cfs in dry years should be enough to initiate bed mobilization, at least locally, but it is probably not enough to precipitate widespread bed mobilization. The recommended peak flows in wetter years should be sufficient to precipitate significant bed mobilization in below normal, above normal, and wet years.

Table 8.5: Bed mobilization flow targets for Sacramento River between Keswick and Bend Bridge during different year types.

	Critical	Dry	Below Normal	Above Normal	Wet
Bed Mobilization		35,000	65,000	85,000	105,000

Some fish biologists have expressed concerns that high flow, even relative modest high flowss, could scour redds and thereby harm salmonid reproduction (ESSA, 2008; Stillwater, 2007). Based on our flow threshold analysis (chapter 5), we doubt that flows below 25,000 cfs will substantially mobilize the bed or scour redds. Much higher flows will significantly mobilize the bed, but the biological impact is not well documented and dependent on timing.

The ideal timing for bed mobilization is in early March after most salmon fry have emerged from the gravel and before bank swallow initiate nesting on cut banks. We expect that most mobilization events will result largely from unregulated run-off that humans are unable to control. While it seem logical that scouring flows would impair salmon reproduction, the natural hydrograph was characterized by multiple bed mobilization events in most years, raising the question of whether high, scouring flows actually limit salmonid reproduction. Under natural conditions, however, young fish would have had abundant floodplain and backwater habitat that is now scarce due to levees and reduced channel complexity.

Bed Scour

Information regarding the bed scour process and the magnitude of flow necessary to scour the bed is limited. While we recognize the potential importance of bed scour processes, we have not recommended any measures to precipitate bed scour due to the high level of uncertainty and the sheer magnitude of flow that may be necessary. We do, however, expect some bed scour to occur during the larges flow events once every ten years or more.

Channel Migration

Bank erosion and channel migration is a natural process that shapes the river ecosystem and provides habitats for riverine species. Bank swallows nest in recently eroded cut banks. Coarse and fine materials eroded from cut banks create substrates for growth of riparian vegetation and spawning salmon respectively. Turbid water resulting from bank erosion can provide important cover habitat for juvenile fish that would otherwise be very vulnerable to predation.

Some degree of bank erosion and channel migration will occur at the bed mobilization flows identified above and the spring pulse flows described below. Flows sufficient to erode unprotected banks already occurs and will continue to occur in wet and above normal years due to unregulated flows irregardless of a flow prescription. Furthermore, removal of bank revetment may be a more cost water efficient measure to facilitate natural channel migration then intentional flow releases. For all of these reasons, we have not developed a specific flow recommendation for bank erosion and channel migration at this time.

Key Uncertainties:

- How much does the bed need to be mobilized? Is it sufficient to barely move the gravel and cobble substrate on the surface of the bed, or is it necessary to achieve full scale mobilization.
- What duration of peak flow is necessary to adequately mobilize the bed?
- How much does or could natural rates of bank erosion contribute to the overall turbidity and sediment load of the Sacramento River.

8.2.5 Spring Base Flow

The purpose of the spring base flow is to substantially increase rearing habitat along channel margins and within high flow channels for 45 to 120 days. Under natural conditions, spring flows (March and April) were consistently the highest, prolonged flow of the water year and resulted in widespread inundation of flood plain habitats. Under existing conditions, spring flows are substantially reduced, and a system of levees prevents widespread floodplain inundations.

We propose base flows to inundate secondary channels for rearing habitat during the spring months (table x). According to a recent study, a large number of secondary channels become fully connected to the channel at flows above 12,000 cfs (Kondolf, 2007). In critical dry years, flows would average 10,000 for thirty days after March 15, but small pulses greater then 12,000 cfs would increase connectivity with rearing habitat. In wetter years, larger flows would presumably create more rearing habitat and connectivity for longer periods of time.

Figure 8.6: Spring Pulse Flows at Bend Bridge

	3/15 - 3/31	4/1 - 4/14	4/15 - 4/30	4/30 - 5/14	5/1 - 5/14	5/15 - 5/31	6/15 - 6/30
Critical	10,000	10,000	8,500				
Dry	10,000	12,000	12,000	8,500			
Below Normal	12,500	12,500	12,500	8,500			
Above Normal	12,500	14,000	14,000	14,000	8,500		
Wet	14,000	14,000	14,000	14,000	14,000	8,500	

Key Uncertainties:

- Do flows in excess of what is necessary to inundate high flow channels create better rearing habitat and more food then flows barely sufficient to inundate these habitats?
- What is the optimal flow and residence time to create ideal rearing habitat conditions (food supply, temperature, and depth) in the secondary channels.

- Is the secondary channel habitat significant enough to substantially improve rearing conditions relative to the rearing habitat in the channel.

8.2.6 Floodplain Inundation Flows

The purpose of the floodplain inundation flows is to inundate floodplains in the Sutter and Yolo flood bypasses for rearing habitat and food web productivity. The flow objective is to create substantial inundated floodplain habitat for 30-60 days between February 15 and April 15 in most year types. To economize on the amount of water necessary to inundate these bypasses, we propose modifying the Tisdale and Fremont weirs to created inundated flood plain habitat more frequently and for a longer duration. Based on the floodplain process analysis in chapter 5, we developed a schedule of flood flow targets for various year types to create good conditions for floodplain rearing and foodweb productivity in nearly all year types (table 7.7).

The floodplain inundation flows are not explicitly included in figure 7.2. The winter and spring pulse flows described above combined with unregulated run-off at Colusa and environmental flows from the Feather and Yuba should be sufficient to achieve the table 7.7 targets.

Table 8.7: Recommended average monthly flows at Verona and Nicolaus on the Feather to create inundated floodplain habitat in the Yolo and Sutter Bypasses for various year types (30-60 days).

	Year Type				
	C	D	BN	AN	W
Nicolaus (Feather)			12,000	15,000	20,000
Freemont Wier		25,000	30,000	37,500	45,000
Tisdale Weir		25,000	30,000	35,000	40,000
Verona		25,000	35,000	45,000	55,000

Key Uncertainties:

- What magnitude of flow is necessary in the Sacramento and Feather Rivers to move water across the bypasses assuming a modified weir structure?
- What is the optimal timing and flow to create optimal habitat conditions on the bypasses (depth, velocity, temperature, residence time) and food web productivity for the estuary?

8.2.7 Spring Snowmelt Recession Limb

The purpose of the spring, snowmelt recession is to periodically provide conditions for recruitment of Fremont cottonwoods, a keystone species in the riparian ecosystem. As discussed in appendix A and chapter 5, recruitment of cottonwoods requires a high spring flow followed by a gradual decline in order to enable cottonwoods set roots into the groundwater on higher surfaces that are relatively immune from scour during subsequent winter floods. An earlier analyses (TNC, 2003) determined that a range of 23,000 cfs to 37,000 cfs inundates the appropriate seedbed for establishment of cottonwood.

Cottonwood trees need not be recruited in all years to ensure a sustained riparian forest ecosystem.

We recommend recruitment flows of 23,000 in above normal years and 37,000 cfs (or somewhere in that general range) in wet years for 4-7 days between mid April and mid May followed by a gradual recession for 8-10 weeks. This flow regime should enable seeds released in mid spring to germinate on relatively high surfaces and then gradually extend roots to the permanent water table before the subsequent growing season.

8.2.8 Summer Base Flow June 15 to September 15

We have designed summer base flows between Keswick and Red Bluff to economically provide suitable conditions for winter run, spring run, and steelhead that spend a temperature sensitive portion of their life cycle between Keswick Dam and Red Bluff diversion Dam (table 7.8). Under natural conditions, these fish would have migrated upstream of Keswick and Shasta, but there mainstem habitat is now limited to the cold tail water provided by reservoir releases. Current base flows are artificially high to deliver water to Sacramento Valley irrigation districts and the Delta. Ideally, these unnaturally high flows could be shifted to the early spring to restore a prolonged spring pulse flow for rearing habitat and aquatic productivity, but providing a more natural flow regime (3,000 to 5,000 cfs) could result in lethal water temperatures for incubating winter run-eggs. Furthermore, flows of only 3,000-5,000 cfs would not provide sufficient water for both diversion into the north valley canals and base flows all the way downstream to the Delta. Therefore, we have proposed an intermediate level summer base that falls at the mid-range between historic base flows and existing base flows between Keswick and Red Bluff.

Table 8.8: Summer base recommendation at various points on the Sacramento River for all year types.

Below Keswick	8,000
Below Red Bluff Diversion	6,000
Below GCID Diversion	4,500
Below Colusa	4,000

Below Red Bluff and the GCID diversions, we have proposed substantially reduced summer base flows in order to shift more flow to the early spring months without disrupting the cold water pool management regime. The primary purpose is to provide better habitat conditions in the spring, but restoring a more natural summer base flow may have environmental benefits in its own right. Summer base flows substantially below the 8,000 cfs needed to inundate off-channel backwaters will create more natural summer conditions and thus may discourage invasive plant and animal species that may out compete natives under the existing artificial summer base flow regime. Seasonally desiccated off-channel habitats may be more productive then perennially inundated wetlands and less likely to harbor exotics predators such as bull frogs and bass. Lower summer water levels may be less beneficial to late germinating invasive vegetation such as tamarisk that can out compete native cottonwoods.

Key Uncertainties:

1. Assuming no changes to the cold water pool management, what flow is necessary to maintain sufficient water temperatures for over summering life stages of winter-run, spring-run, late fall-run and steelhead?
2. Will low flows and corresponding higher temperatures increase populations of non-native warm water fish that prey upon or compete with native species?
3. Will summer base flows be sufficient between Red Bluff and GCID to maintain water temperature conditions suitable for juvenile salmonids or adult migrating salmonids?
4. Will more "natural" conditions provide better habitat and feeding conditions for native species?

8.3 Feather River

Summary recommendations for Sacramento River base flows, key ecological flows, and a flow schedule are presented in tables 7.1 – 7.3. Illustrative flow recommendation hydrographs for each year type are presented in figure 7.2.

Table 8.9: Feather River Environmental Flow Targets for Bend Bridge and Verona

	Critical	Dry	Below Normal	Above Normal	Wet	Location
Bed Mobilization		10,000	20,000	55,000	50,000	Bend
Floodplain Inundation		6,000	8,000	10,000	12,000	Verona
Riparian Establishment Flow				10,000	12,000	Bend
Bed Scour	No Recommendation					
Channel Migration						

Table 8.10: Feather River Minimum Base Flow Targets for Oroville

	Critical	Dry	Normal Dry	Normal Wet	Wet
Fall base flow	1,250	1,250	1,300	1,600	1,750
Winter base flow	1,500	1,700	1,850	2,750	3,500
Spring base flow	2,000	2,700	3,200	6,500	8,000
Spring rise	2,750	5,500	8,000	10,000	12,500
Summer Base	1,300	1,700	2,000	2,000	2,000

Table 8.11: Feather River Environmental Flow Targets (Timing and Duration)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
Geomorphic				▨	🟨	🟨	▨		Optimal 2/15 -3/15*			
Floodplain Inundation					🟨 Only 45 Days	🟨						
Riparian Establishment Flow							🟨					
Riparian Recession Limb								🟨	🟨			
Spring Rise							🟨	🟨				
Fall Base Flow	🟨	🟨										🟨
Winter Base Flow			🟨	🟨	🟨							
Spring Base Flow						🟨	🟨	🟨				
Summer Base Flow									🟨	🟨	🟨	

8.3.1 Fall Base Flows

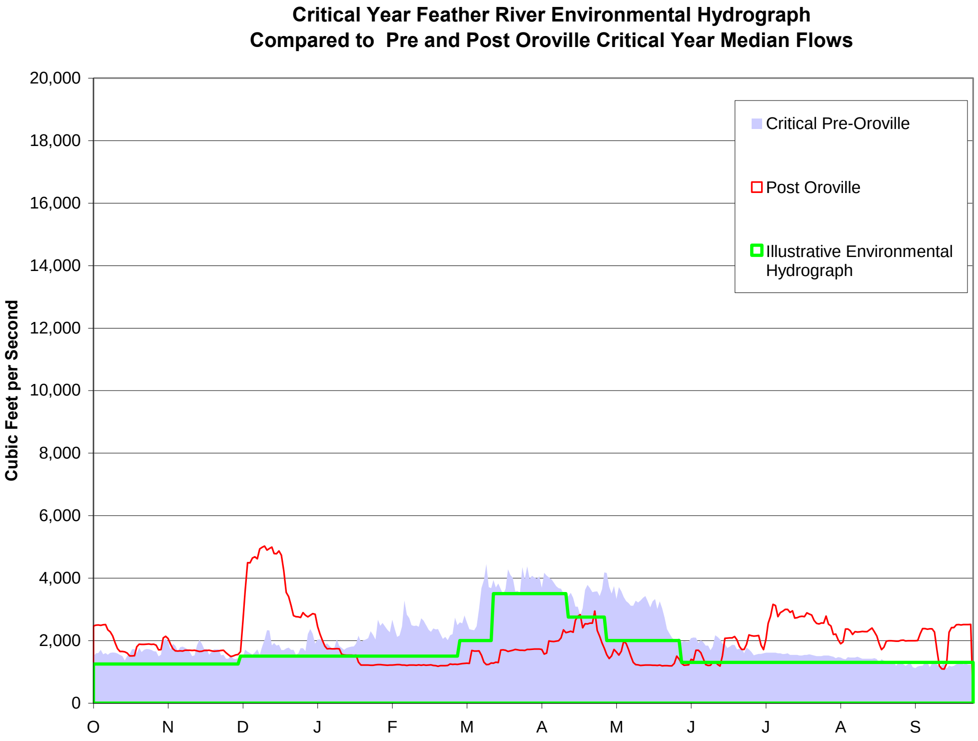
We propose stepping flows down from a stable summer base flow (see below) in late September (table 7.10) to fall spawning flows specified by the recent Oroville relicensing proceeding. The new minimum instream flows below Thermalito Afterbay range from 1,000 cfs in the late spring and summer to 1,200 -1,700 cfs during the fall winter months. Under both natural and regulated conditions, flows in early fall are the lowest flows of the year. The primary purpose of lowering base flows in the fall closer to their historic and regulatory minimum levels is to economize on water and shift the saved water to the spring months when it is more important. The secondary purpose is to provide stable base flows for spring and fall-run spawning and potentially to trigger spring-run spawning. The fall base flows must be stable to avoid dewatering or redds that may occur when flows are substantially dropped from the norm.

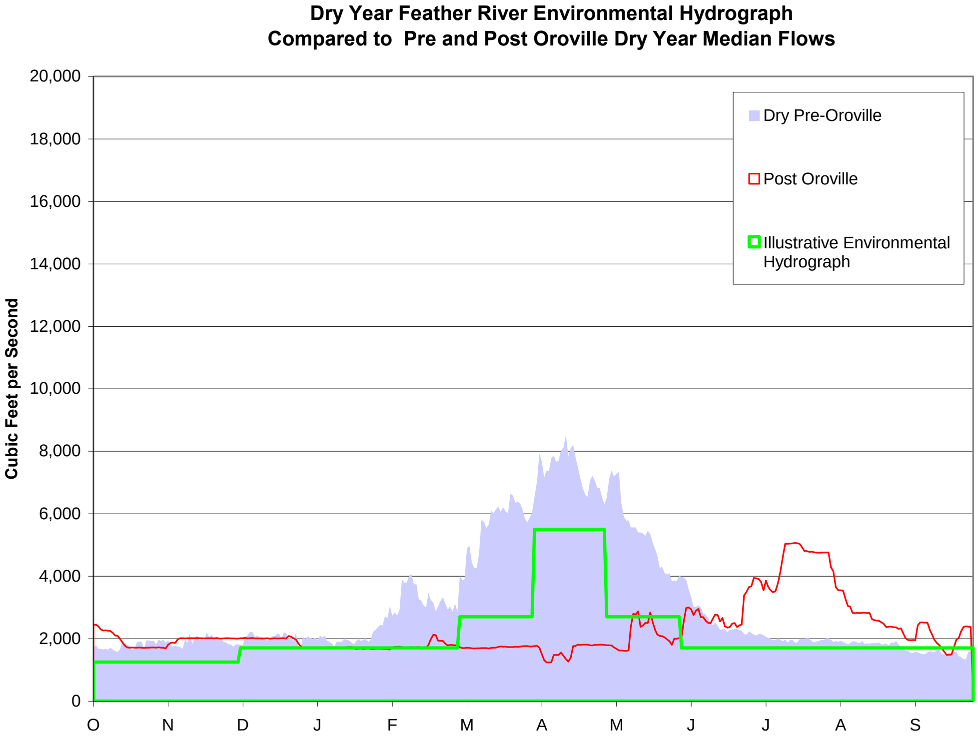
Key Uncertainties

- Are proposed fall base flows sufficient for area of spawning habitat?

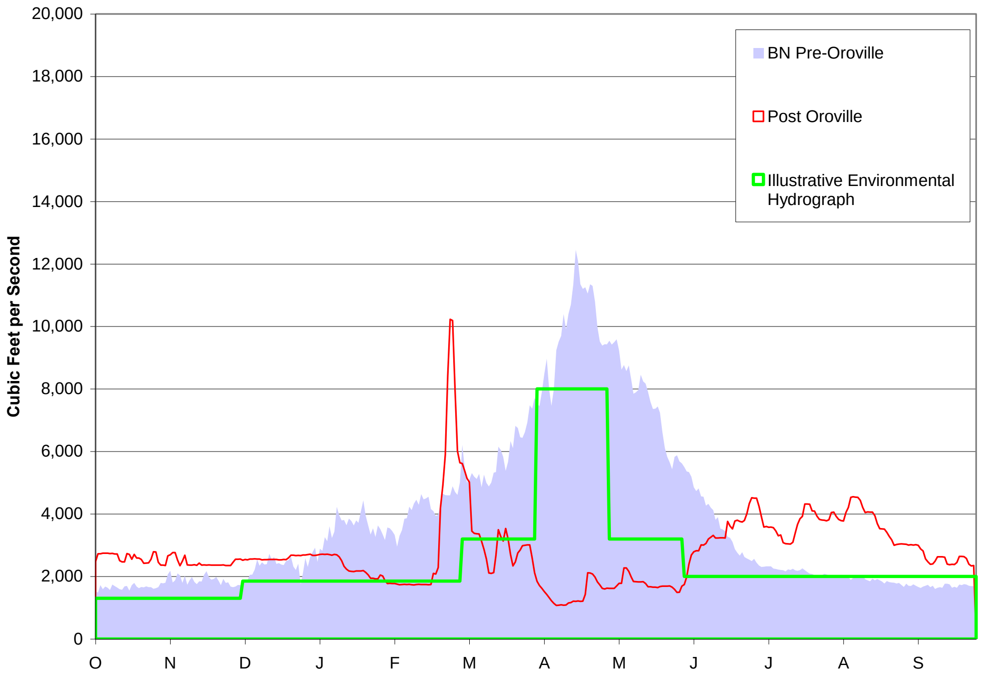
Will reduce fall base flows cause adverse impacts in the Delta ecosystem?

Figure 8.3: Illustrative environmental hydrographs for five year types on the Feather River relative to pre and post Oroville hydrographs.

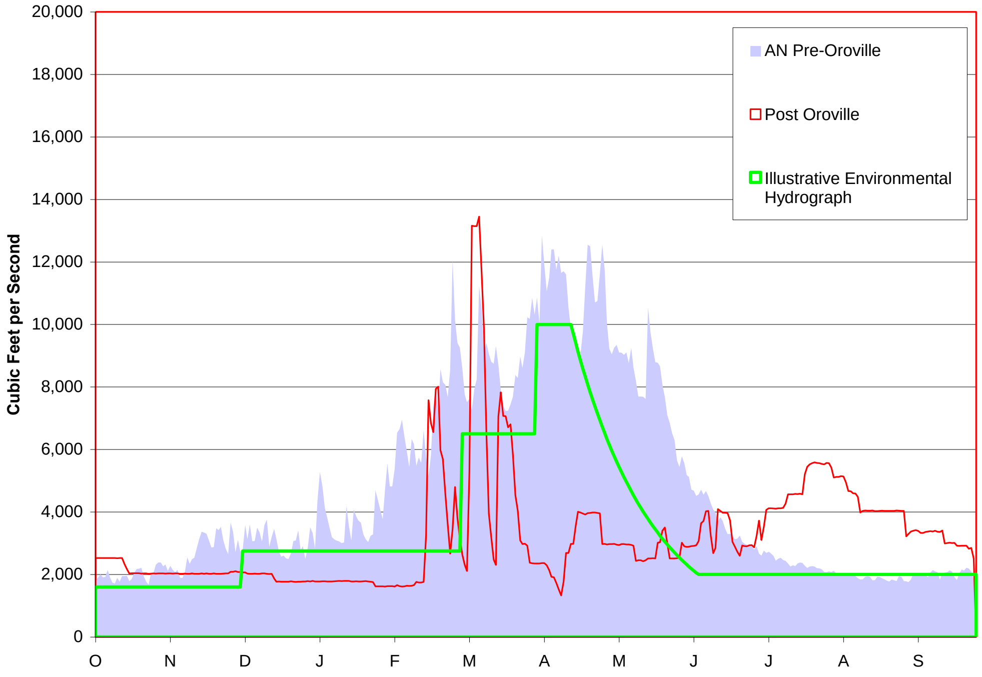


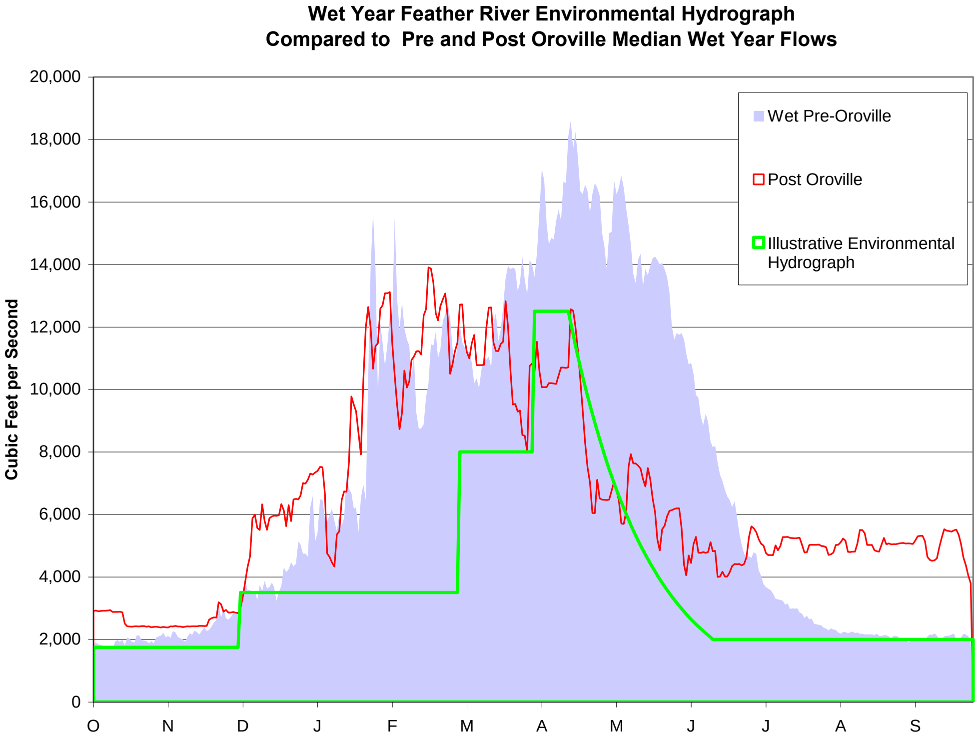


Below Normal Year Feather River Environmental Hydrograph Compared to Pre and Post Below Normal Oroville Median Flows



Above Normal Year Feather River Environmental Hydrograph Compared to Pre and Post Oroville Above Normal Median Flows





8.3.2 Winter Base Flows

The purpose of the winter base flows is to provide stable conditions for incubating salmonids and reduce flashy regulated hydrology that can result when run-off from unregulated tributaries, particularly the South Fork Yuba, is not modulated by less flashy natural hydrology from the larger, regulated watersheds. We recommend base flows of between 1,500 cfs in critical dry years and 3,500 cfs in wet years (table 7.10), which is similar to both existing regulated conditions and pre-dam historical conditions.

The winter base flows are a minimum base flow and are designed to occur in combination with unregulated run-off and flood control releases. Figure 7.3 shows the winter base flows as a straight line, but it is just a base flow that supports larger, unregulated peak flows. As a result, actual flows below the confluence with the Yuba will be far more variable then depicted in figure 7.3.
Fairly substantial winter base flows combined with run-off events from less regulated tributaries will increase the frequency of inundation of channel margins and secondary channels that may serve as important rearing habitat.

8.3.4 Winter and Spring Peak Flows

The geomorphic flow targets discussed below may require additional releases from Shasta but are not explicitly included in figure 7.3 because they are short duration flow events that would be constructed upon the spring rise or ordinary flood control releases. Smaller magnitude spring pulse flows for fish rearing discussed below should be sufficient, particularly if reshaped, to achieve geomorphic targets.

Bed Mobilization
We recommend increasing the frequency of channel migration and bed mobilization flows during dry and below normal years for the reasons discussed in Appendix B. On the basis of thresholds discussed in chapter six, we recommend measures to achieve bed mobilization flows in most years (table 7.5). Based on the analysis of flow thresholds presented in chapter five, 35,000 cfs in dry years should be enough to initiate bed mobilization, at least locally, but it is probably not enough to precipitate widespread bed mobilization. The recommended peak flows in wetter years should be sufficient to precipitate significant bed mobilization in below normal, above normal, and wet years.

Table 8.12: Bed mobilization flow targets for Feather River below Oroville

	Critical	Dry	Below Normal	Above Normal	Wet
Bed Mobilization		10,000	25,000	35,000	50,000

Some fish biologists have expressed concerns that high flow, even relative modest high flowss, could scour redds and thereby harm salmonid reproduction on the Sacramento River (ESSA, 2008; Stillwater, 2007). Because are bed mobilization flows for the Feather River are based on statistical estimates rather then empirical evidence of bed mobility, the potential for red scour is a big uncertainty, but we doubt it will occur at 25,000 cfs or less and the greater magnitude flows prescribed for above normal and wet are likely to happen from flood control releases regardless of our flow recommendations.

The ideal timing for bed mobilization after late February when most salmon fry have emerged from the gravel. We expect that most mobilization events will result largely from unregulated run-off that humans are unable to control. While it seem logical that scouring flows would impair salmon reproduction, the natural hydrograph was characterized by multiple bed mobilization events in most years, raising the question of whether high, scouring flows actually limit salmonid reproduction. Under natural conditions, however, young fish would have had abundant floodplain and backwater habitat that is now scarce due to levees and reduced channel complexity.

Bed Scour
Information regarding the bed scour process and the magnitude of flow necessary to scour the bed is limited. While we recognize the potential importance of bed scour processes, we have not recommended any measures to precipitate bed scour due to the high level of uncertainty and the sheer magnitude of flow that may be necessary. We do, however, expect some bed scour to occur during the larges flow events once every ten years or more.

Channel Migration

Bank erosion and channel migration is a natural process that shapes the river ecosystem and provides habitats for riverine species. Bank swallows nest in recently eroded cut banks. Coarse and fine materials eroded from cut banks create substrates for growth of riparian vegetation and spawning salmon respectively. Turbid water resulting from bank erosion can provide important cover habitat for juvenile fish that would otherwise be very vulnerable to predation.

Some degree of bank erosion and channel migration will occur at the bed mobilization flows identified above and the spring pulse flows described below. Flows sufficient to erode unprotected banks already occurs and will continue to occur in wet and above normal years due to unregulated flows irregardless of a flow prescription. Furthermore, removal of bank revetment may be a more cost water efficient measure to facilitate natural channel migration then intentional flow releases. For all of these reasons, we have not developed a specific flow recommendation for bank erosion and channel migration at this time.

Key Uncertainties:

- How much does the bed need to be mobilized? Is it sufficient to barely move the gravel and cobble substrate on the surface of the bed, or is it necessary to achieve full scale mobilization.
- What duration of peak flow is necessary to adequately mobilize the bed?
- How much does or could natural rates of bank erosion contribute to the overall turbidity and sediment load of the Sacramento River.

8.3.5 Spring Base Flow

The purpose of the spring base flow is to substantially increase rearing habitat along channel margins and within high flow channels for 45 to 120 days. Under natural conditions, spring flows (March and April) were consistently the highest, prolonged flow of the water year and resulted in widespread inundation of flood plain habitats. Under existing conditions, spring flows are substantially reduced, and a system of levees prevents widespread floodplain inundations.

On the Feather River, we do not have good information regarding the flows necessary to inundate back-water channels. As a result we developed spring flow targets based on historical hydrology and an assessment of the flows necessary to inundate the Sutter Bypass (table 7.13). Wetter year spring flow pulses begin later in the spring and last longer, while dryer year targets economize on water early to get salmon out of the river before temperatures could become a problem in the lower Sacramento.

Figure 8.13: Spring Pulse Flows below Oroville

	3/1- 3/14	**3/14- 3/30**	**4/1- 4/14**	**4//14 - 4/30**	**5/1 - 5/14**	**5/15 – 5/31**
Critical	2,000	3,500	3,500	2,000		
Dry	2,700	2,700	5,500	5,500	2,700	
Below Normal	3,200	3,200	8,000	8,000	3,200	
Above Normal	6,500	6,500	10,000	10,000	5,000	3,000
Wet	8,000	12,500	12,500	11,000	6,000	4,000

Key Uncertainties:

- Do flows in excess of what is necessary to inundate high flow channels create better rearing habitat and more food then flows barely sufficient to inundate these habitats?
- What is the optimal flow and residence time to create ideal rearing habitat conditions (food supply, temperature, and depth) in the secondary channels.
- Is the secondary channel habitat significant enough to substantially improve rearing conditions relative to the rearing habitat in the channel.

8.3.6 Floodplain Inundation Flows

The purpose of the floodplain inundation flows is to inundate floodplains in the Sutter and Yolo flood bypasses for rearing habitat and food web productivity. The flow objective is to create substantial inundated floodplain habitat for 30-60 days between February 15 and April 15 in most year types. To economize on the amount of water necessary to inundate these bypasses, we propose modifying the Tisdale and Fremont weirs to created inundated flood plain habitat more frequently and for a longer duration. Based on the floodplain process analysis in chapter 5, we developed a schedule of flood flow targets for various year types to create good conditions for floodplain rearing and foodweb productivity in nearly all year types (table 7.7).

The floodplain inundation flows are not explicitly included in figure 7.3. The spring pulse flows described above combined with unregulated run-off from the Sacramento and Yuba Rivers will be sufficient to achieve the table 7.7 targets.

Table 8.14: Recommended average monthly flows at Verona and Nicolaus on the Feather to create inundated floodplain habitat in the Yolo and Sutter Bypasses for various year types (30-60 days).

	Year Type				
	C	D	BN	AN	W
Nicolaus (Feather)			12,000	15,000	20,000
Freemont Wier		25,000	30,000	37,500	45,000
Tisdale Weir		25,000	30,000	35,000	40,000
Verona		25,000	35,000	45,000	55,000

Key Uncertainties:

- What magnitude of flow is necessary in the Sacramento and Feather Rivers to move water across the bypasses assuming a modified weir structure?
- What is the optimal timing and flow to create optimal habitat conditions on the bypasses (depth, velocity, temperature, residence time) and food web productivity for the estuary?

8.3.7 Spring Snowmelt Recession Limb

The purpose of the spring, snowmelt recession is to periodically provide conditions for recruitment of Fremont cottonwoods, a keystone species in the riparian ecosystem. As discussed in appendix A and chapter 5, recruitment of cottonwoods requires a high spring flow followed by a gradual decline in order to enable cottonwoods set roots into the groundwater on higher surfaces that are relatively immune from scour during subsequent winter floods. Since we did not have estimates of flows suitable for riparian recruitment on the Feather River, we estimated a seedling establishment flow target based on the Sacramento riparian recruitment target. We simply scaled down the Sacramento target based on the ratio of the seedling establishment flow to the Q1.5. The seedling establishment flow on the Sacramento (23,000 – 30,000 cfs) is twenty seven to thirty seven percent of the bankfull discharge (Q1.5 to Q2) on the Sacramento. Assuming a similar proportional relationship on the Feather River, flows in the range of 9,500 to 18,000 would be suitable for seedling establishment.

We recommend seedling establishment flows of 10,000 in above normal years and 12,500 cfsin wet years for 4-7 days between mid April and mid May followed by a gradual recession for 8-10 weeks. This flow regime should enable seeds released in mid spring to germinate on relatively high surfaces and then gradually extend roots to the permanent water table before the subsequent growing season.

8.3.8 Summer Base Flow June 15 to September 15

The purpose of the summer base flow is to provide suitable temperature and rearing conditions for over summering salmonids, both juvenile and adult spring-run and steelhead. We propose base flow targets ranging from 1,300 in critical dry years to 2,000 cfs in above normal and wet years. These flows are very similar to natural summer base flows and are higher then the minimum existing minimum flows established during the recent relicensing proceedings. Existing minimum regulatory flows are 1,000 cfs in the summer. Existing actual flows are far higher then are recommendation.

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APPENDIX A

LITERATURE REVIEW OF ENVIRONMENTAL FLOW METHODS

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LITERATURE REVIEW OF ENVIRONMENTAL FLOW METHODOLOGIES

Over the past five decades, the development and application of environmental flow methodologies (EFMs) has rapidly progressed, as a means to help sustain or restore natural aquatic functions and ecosystems in the face of increasing demands for limited water resources. EFMs are science-based processes for assessing and/or recommending instream flows for regulated rivers. Their purpose may be as general as maintaining a healthy riverine ecosystem or as specific as enhancing the survival of targeted aquatic species. The growing prominence of EFMs in river management planning reflects a trend towards more sustainable use of the world's freshwater resources and a shift in focus from water quality to water *quantity* as a major factor in the degradation of rivers (O'Keeffe 2000).

In a comprehensive study of environmental flow methodologies, Tharme (2000) documented the existence of more than 200 EFMs, recorded worldwide. These included various modifications and hybrids of some commonly applied methods, site-specific approaches with limited applications, and procedures that are no longer in use. In actuality there are only a few dozen EFMs that are still widely applied. They can be divided into four major categories: 1) hydrological, 2) hydraulic rating, 3) habitat simulation, and 4) holistic methodologies (Tharme 2000). An overview of each of these categories is provided below, along with general strengths, weaknesses, and associated trends.

1.1. Hydrological Methods

Hydrological methodologies make up the largest proportion (30%) of environmental flow methodologies developed (Tharme, 2000). Hydrological methods are usually simple office procedures that recommend a proportion of a river's historical unregulated or naturalized flow regime as the minimum flow to maintain a fishery or other aquatic features. Recommended flows may be given on a monthly, seasonal, or annual basis. For example, the Tennant (Montana) method suggests 20% of mean annual flow (MAF) during the wet season and 40% MAF during the dry season to maintain "good" river conditions. Because of their simplicity and low resolution, Tennant and other hydrological methods are most appropriate for early reconnaissance-level project planning, to provide relatively quick and inexpensive estimates of flows to allocate for environmental purposes. Although biological factors are not explicitly considered in these methods, most were developed with some general biological basis (Caissie and El-Jabi 1995). In addition, hydrological methods assume that a minimum flow within the historic flow range for a river will sustain some proportion of native aquatic biota because the species survived such conditions in the past (Jowett 1997).

Hydrological methods have the primary advantages of being simple, straightforward, and relatively inexpensive to apply. Most require only historical flow records for a site, with little or no additional fieldwork. The simplicity of these methods, however, is also their greatest weakness. Because they do not incorporate site-specific habitat data, their ecological validity is often questionable (King et al. 2000). For example, these methods are frequently applied without regard to artificial changes in channel conditions (due to flow regulation or man-made structures) that may influence the ecological impact of recommended flows. EFMs in this category also should not be applied to river systems that do not approximate in size and type the reference river systems on which they were developed. Many hydrological methods do not address ecologically important intra- and interannual variations in flows. And unlike other methods, hydrologically based EFMs usually cannot be used to compare alternative flow regimes. Finally, for some river systems it may be difficult to obtain the unregulated or naturalized flow data necessary to calculate recommended flows.

Despite their many limitations, Tharme (2000) suggested that hydrological methods will continue to be the EFMs of choice for the foreseeable future. However, we can expect to see progress in their development towards more ecologically defensible and sophisticated methodologies. The Range of Variability Approach (RVA) is one such recently developed EFM that is considered to represent a significant advance over earlier hydrological methods. Unlike other EFMs in its category, the RVA captures the complex intra- and interannual variability of natural flow regimes over multiple temporal scales, incorporates a large number of ecologically based hydrologic indices in its analysis, and utilizes an adaptive management program for monitoring and refinement (Richter et al. 1996, 1997). Since its inception, the RVA has attracted considerable interest among river scientists and managers as a new class of ecologically grounded hydrologically based environmental flow methodologies (King et al. 2000).

1.2. Hydraulic Rating Methods

Hydraulic rating methodologies comprise 11% of the global total of EFMs. They differ from purely hydrology-based methods in that they incorporate site-specific information on hydraulic parameters, such as wetted perimeter or maximum depth, as measured across riffles or other limiting river cross sections. These parameters are used as surrogates for the habitat available for target biota such as fish or macroinvertebrate communities. Hydraulic rating methods assess changes in the habitat surrogates in response to changes in discharge. Recommended flows are commonly set at a breakpoint in the parameter-discharge curve, interpreted as the flow below which habitat decreases rapidly with a decrease in flow and above which habitat increases slowly with an increase in flow (Loar et al. 1986).

Although they require some fieldwork and data analysis, hydraulic rating methods enable a relatively quick and simple assessment of flows for maintaining habitat of target biota. They are considered more advanced and biologically relevant than hydrological methods. Their inclusion of site-specific field measurements better adapts them to different river systems. Hydraulic rating methods, however, are based on a number of simplistic assumptions that often cannot be verified. Key among these is that the chosen hydraulic variable(s) can be used to determine the flow requirements of the target species. In addition, the validity of results is highly dependent on appropriate sampling of critical river cross sections and proper identification of a breakpoint in the parameter-discharge curve. The latter is frequently complicated by the existence of multiple breakpoints or the lack of any defined breakpoint in the curve. And like most hydrological methods, EFMs in this category generally do not address ecologically important intra- and interannual variations in flows.

In the past decade there have been few advances in the development or application of hydraulic rating methodologies. Instead, this category of EFMs seems to have been superceded by the more advanced habitat simulation methodologies for which they are precursors. The Wetted Perimeter Approach, the best-known EFM in this category, is still widely applied in North America and globally (Reiser 1989, King et al. 2000). However, it is likely that many other hydraulic rating methods will gradually fall into obsolescence as the science of EFMs advances in alternate directions (Tharme 2000).

1.3. Habitat Simulation Methods

Habitat simulation methodologies (28%) rank second only to hydrological methods in proportion of total EFMs. This group of flow methodologies includes the U.S. Fish and Wildlife Service's Instream Flow Incremental Methodology (IFIM), which is the most widely used EFM in North America and the world (Reiser 1989, Tharme 2000). IFIM and many other habitat simulation methods comprise systems of highly sophisticated computer modeling techniques that integrate site-specific hydraulic and hydrologic data with species specific habitat preference data (in the form of habitat suitability curves). Computer outputs are usually in the form of habitat usability-flow discharge curves for the various factors of interest, e.g., different life stages of one or two fish species. Practitioners evaluate these curves and determine flow regimes based on the levels of protection (habitat usability) desired for each factor of interest. Because there is considerable potential for conflicting habitat requirements in this final step, it is necessary to have clear management objectives and a good understanding of the stream ecosystem when using IFIM and other habitat simulation methods to develop flow regimes.

Habitat simulation methods are flexible and adaptable. They incorporate site-specific and species specific information, so can be tailored for particular conditions and management goals. They can be used to analyze flow-related trade offs among multiple species and life stages. They may be modified to recommend flows for riparian vegetation, sediment flushing, recreation, and any number of other instream purposes. They are capable of addressing ecologically important intra- and interannual variations in flows for target species. Habitat simulation methods are also often perceived as scientifically objective and legally defensible; thus, they may be suitable for allocating instream flows in highly controversial situations (Estes 1996).

The focus of habitat simulation methods on specific target species and/or instream uses raises the risk that other essential components of the stream ecosystem may be overlooked (Prewitt & Carlson 1980). On the other hand, when these methods are used to address multiple management objectives for a river system, there are no set procedures for resolving conflicting flow requirements. The flexibility that habitat simulation methods provide make them among the most difficult EFMs to apply and interpret. Another important consideration, especially for developing countries, is that habitat simulation methods are often time-consuming, costly, and require considerable technical and scientific expertise for proper application. Modeling applications can be run without sufficient understanding of input and output processes; therefore, there is high potential for misuse by improperly trained persons. Other important sources of error or bias for modeling outputs include selection of representative cross sections for collecting hydraulic data, and construction of species-specific habitat suitability curves. Finally, a commonly cited criticism of PHABSIM, the modeling system used with IFIM, is the seeming lack of relation between fish and habitat usability estimates produced by the models (Orth and Maughan 1982).

Habitat simulation models, though the subject of much criticism, are still highly regarded by many river scientists. Current trends in their development are more advanced modeling techniques, multi-dimensional graphics, and integration of GIS display platforms.

1.4. Holistic Methods

These methods are relatively new to the science of environmental flow management. They were first documented by Tharme (1996) and currently make up 7.7% of total EFMs (Tharme 2002). Holistic approaches rely largely on multidisciplinary expert panels to recommend instream flows (Tharme 2000). They represent a significant departure from earlier environmental flow methods, in that their recommendations are almost wholly subjective. However, more advanced holistic methods, such as the Building Block Methodology (BBM), may utilize several of the analytical tools described for other EFMs to assist in the decision-making process (Tharme 2000). An early step in the BBM and some other holistic methods is identification of the magnitude, timing, duration, and frequency of important flow events for various ecosystem components and functions. The decision-making process for integrating these flow events may include a number of activities, including workshops, site visits, and limited data collection and analysis. The final output of the consensus process is a recommended flow regime to meet various specific management objectives.

Most holistic methods are relatively quick and inexpensive to apply. They have limited requirements for technical expertise and hydrologic data. And with appropriate interdisciplinary representation, these methods can comprehensively address all major components of the riverine ecosystem, including geomorphological, riparian, biological, water quality, social and other elements. Holistic methods can recommend flows at a variety of temporal scales. They are site-specific and allow for assessment of whole stretches of river rather than extrapolation from sample cross sections. The major weakness of holistic methods is the subjectivity of their approach, which may open their findings to controversy and criticism.

Holistic methods are still very much in the infancy of their development. Most of these methods have their roots in South Africa and Australia. Few have been applied outside of these countries of origin. Application of holistic methods for environmental flow management is expected to grow rapidly over the next decade, as EFMs become better established as river management tools in developing countries. Holistic methods are well suited for use in these countries, where data, finances, and technical expertise are frequently limited.

2. METHOD FOR DEVELOPING ENVIRONMENTAL FLOW RECOMMENDATIONS FOR THE SACRAMENTO AND FEATHER RIVERS

We have employed a version of the holistic approach practiced in South Africa and Australia (King et. al. 2000) to identify an environmental flow regime for the Sacramento River. This approach relies heavily on hydrological evaluations, previous studies, and expert opinion to estimate environmental flow requirements and develop a long-term adaptive management plan for implementing and refining an environmental flow regime over time. The results of the holistic approach provide a framework for increasing knowledge regarding the relationship between flow and environmental objectives and refining water management practices over time. The output of the holistic method envisioned here provides not only an estimate of environmental flow requirements, but more importantly, an explicit identification of key assumptions and uncertainties that need to be tested overtime to more accurately describe the flow requirements necessary to achieve environmental objectives.

We made two important assumptions in generally applying this method to the Sacramento River.

- Similarities in both the restoration objectives and the hydrologic, geomorphic, and ecological conditions on the Sacramento River will result in relatively similar prescriptions for environmental management flows. We believe this assumption is well supported by the environmental conditions and historical alteration of this river.

- The flow necessary to achieve restoration objectives may vary greatly depending on non-flow restoration actions such as improving spawning habitat, reconstructing degraded channel, removing levees to restore floodplain habitat, modifying and screening water diversions, reducing polluted run-off, managing ocean harvest, and other factors. In general, non-flow restoration actions will reduce the amount of water necessary to achieve restoration objectives.

The holistic approach applied in this study consists of the following 6-step process to identify an environmental flow regime:

1. Identify specific environmental objectives (i.e,. target species, aquatic and riparian communities, and desired ecological conditions that are flow dependent).
2. Approximate the timing, magnitude, frequency, and duration (TMDF) of flows necessary to support target species, communities and desired ecological processes.
3. Compare existing vs. historical hydrology to understand natural hydrologic patterns and how they have been altered.
4. Identify obvious gaps between objective flow requirements and existing flows.

5. Develop an environmental flow hydrograph to achieve ecological objectives based upon a clear understanding of historical and existing hydrologic patterns, and identify key hypotheses and uncertainties regarding the relationship between flow patterns and environmental objectives.
6. Design an adaptive management program to further test and refine environmental flows.

1) Identify specific environmental objectives (i.e,. target species, aquatic and riparian communities, and desired ecological conditions that are flow dependent).

Well-articulated target ecological conditions and desired species and communities are necessary for establishing environmental flows. Despite the correctly vogue concept of restoring ecosystem processes and avoiding species specific approaches, there is no getting around the fact that key species need specific hydrologic conditions at specific times. This analysis will include both aquatic and riparian communities and the flow parameters necessary to sustain these communities such as floodplain inundation, appropriate water temperature, or creation of structural habitat through geomorphic processes. These specific environmental objectives may vary by region, sub-basin, and reach of the river.

2) Approximate the timing, magnitude, frequency, and duration (TMDF) of flows necessary to support target species, communities and desired ecological processes.

An environmental flow regime encompasses the adequate timing, magnitude, duration, and frequency of flows necessary to support target species and facilitate specific ecological processes encompassed in the stated environmental objectives. Where we understand the life cycle timing of various target species, it is relatively easy to identify the approximate timing and duration of flows necessary to support different life stages of target species. Estimating the required flow magnitude is far more difficult but can be informed by field data, results of numerical models, and general relationships described in the literature. Most short lived target species require adequate flows each year to reproduce, while longer lived species can sustain their populations with a lower frequency of flow conditions conducive to reproduction. For example, riparian forest species may only require recruitment flows every five to ten years to establish new seedlings.

Estimating the magnitude of flows necessary to support or optimize conditions for target species and processes is by far the most difficult element of the environmental hydrograph to approximate. Environmental engineers and biologists have developed relatively elaborate methods for determining ideal flow regimes such as physical habitat simulation (PHABSIM) and Instream Incremental Flow Methodology (IFIM) to identify optimum flow magnitudes based on known habitat preferences of target species, measured habitat conditions (velocity and depth) at various flows, and numerical models that predict habitat conditions at a range of flows. Numerical models that describe the width, depth, and velocity of the rivers at various discharges are useful for predicting river stage and temperature at various locations, factors that are important considerations for habitat or facilitating geomorphic and hydrologic processes. As discussed above, these models tend to focus on the needs of specific species and can sometimes produce results that are inconsistent with both holistic ecological process restoration and common sense. Furthermore, these models are often not calibrated, particularly at higher flows relevant to riparian recruitment, geomorphic processes, and spring outmigration temperatures. Nevertheless, we utilized the results of these models as a guide combined with other information to develop our environmental flow management hypothesis.

Where possible, we relied on actual data and measurements to estimate the flows necessary to achieve suitable conditions to support biological, riparian, and geomorphic objectives for temperature, floodplain inundation, and bed mobilization. In particular, we relied on USGS temperature gauges to characterize the relationship between temperature and flow. Similarly, we relied on previous studies of the rivers to characterize flows necessary to mobilize bed material and inundate the floodplain.

3) Compare existing vs. historical hydrology to understand natural hydrologic patterns and how they have been altered.

Analyses of historical hydrologic data is useful for describing natural patterns and identifying potential links between hydrology and the requirements necessary to maintain species and precipitate key processes. An analysis of historical patterns can provide clues about the timing, magnitude, duration, and frequency of flows under which target species have evolved. Identification of major changes between historical and hydrologic patterns combined with the life history requirements of various species can help generate hypotheses about how flow regulation may be limiting target species. We will use the an analysis similar to the Index of Hydrologic Alteration approach (Richter et al. 1996) and the Hydrograph Component Analysis (HCA) (Trush et al. 2000) to evaluate changes in flow patterns. The analysis similar to the IHA provides a quick statistical overview of how several important hydrologic attributes have changed. The analysis similar to the Hydrograph Component Analysis (HCA) method developed by McBain and Trush provides a detailed graphical analysis of historical and existing hydrologic conditions. While valid and useful, the statistical analysis in the IHA method is not substitute for visually comparing and evaluating key components of the pre- and post-dam hydrographs. Similarly, visual comparisons of pre- and post-alteration hydrographs don't always reveal important changes identified by the IHA method.

4) Identify obvious gaps between objective flow requirements and existing flows.

An analysis of historical flow patterns combined with an approximation of the TMDF of flows necessary to achieve objectives compared with the regulated flow regime can help illustrate obvious gaps between regulated flows and flows that may be necessary to achieve environmental objectives. We will plot TMDF flow requirements developed in Step 2 as an annual hydrograph and compare it with average regulated and historical conditions.

5) Develop an environmental flow hydrograph to achieve ecological objectives based upon a clear understanding of historical and existing hydrologic patterns, and identify key hypotheses and uncertainties regarding the relationship between flow patterns and environmental objectives.

This project identifies hypothetical restoration flow regimes but recognizes that the most reliable method for developing a restoration flow regime is through a long-term adaptive management program including a series of trials that test the effectiveness of various flow prescriptions. The purpose of developing the hypothetical flow regime is to develop a comprehensive hypothesis regarding the range of flows that may be necessary to restore ecological processes to the Sacramento River. However, the assumptions and uncertainties associated with the hypothetical flow regime are as important as the flow regime itself.

6) Design an adaptive management program to further test and refine environmental flows.

To cost effectively achieve restoration, managers will ultimately need to test these assumptions and limit the uncertainties through an adaptive management program consisting of a combination of numerical modeling, pilot flow studies, model calibration, and long-term restoration implementation.

APPENDIX B

CONCEPTUAL MODELS
FOR
GEOMORPHIC PROCESSES, FREMONT COTTONWOODS,
AND CHINOOK SALMON

APPENDIX B: CONCEPTUAL MODELS

Geomorphic Conceptual Model

1.0 Geomorphic Conceptual Model

Geomorphic processes are generally initiated at threshold flow levels. Bed mobilization and floodplain inundation do not occur until flows reach a threshold level sufficient to flow over bank or create sheer stresses necessary to mobilize gravel. Theoretically, no benefit occurs unless the threshold flow is achieved. No amount of flows less than the threshold will initiate bed mobilization or floodplain inundation, but in reality the actual threshold flow varies spatially from reach to reach. Research from several gravel bedded river systems indicates that a flow with a natural (unregulated) recurrence interval of every 1.5 years is generally needed to mobilize the bed and initiate over bank flows (Leopold et al. 1964). In reality, however, the threshold flows necessary to initiate geomorphic processes naturally vary from reach to reach depending on channel dimensions, slope, and the size of bed material. In general, sand bedded reaches mobilize at lower flows than gravel bedded reaches with larger particle sizes. Similarly, low gradient reaches flood at lower discharges than steeper reaches, particularly where large woody debris is allowed to accumulate.

Human modifications of the channels from their natural state have changed the relationship between flows and geomorphic processes and have therefore complicated the already difficult task of determining the flows necessary for precipitating various geomorphic processes. Gravel and channel restoration projects have changed and could continue to change the particle size of gravels and the channel dimensions and will thus further change the relationship between flow and geomorphic processes. More importantly, there is no single bed mobility threshold for any reach of the Sacramento River or any other river channel due to spatial vaiabilty in particle size and channel form (Kondolf et al, 2000; Wilcock, 1996).

There are varying degrees of bed mobilization, further complicating the definition of mobility and its distinction with bed scour. For this study, we attempted to estimate the flows necessary to mobilize and scour the bed. Bed mobility and bed scour are two different processes that occur at different flow thresholds. We use the term bed mobility to refer to mobilization of the surface of the channel bed. Bed scour is the process of scouring the bed deeper than its coarse surface layer. Incipient bed mobility is the threshold at which bed material begins to mobilize and occurs when the ratio of the critical sheer stress to the D_{50} equals 1. Incipient mobility can cause small movement of gravel across the top of the riffle without general mobilization of the riffle surface. Relatively frequent (every 1–2 years) incipient motion of gravels on a riffle may be adequate for certain objectives such as flushing fines from the gravels, but is probably not sufficient for certain geomorphic objectives such as restoring sediment transport or maintaining a dynamic, alternating bar sequence (Trush et al. 2000). General bed mobility mobilizes the entire riffle surface and occurs when the ratio of critical sheer stress to particle size D_{50} exceeds 1.3. General bed mobility may be necessary for restoring basic alluvial functions such as transporting coarse sediment from one riffle to the next.

Lastly, there is relatively little information regarding the flows necessary to perform various geomorphic objectives. Geomorphic processes associated with these objectives occur at very high flows, when field measurement is difficult. Hydraulic models and equations have been applied on the Sacramento to provide insight into the flows necessary to mobilize the bed and banks and inundate the floodplain, but in many cases these models have not been adequately calibrated at high flows or do not accurately describe the actual hydraulics at specific cross sections (Kondolf, 2000). Empirical observations are generally more reliable, but are often limited to specific study sites. In this study, we have relied on previously reported field measurements, modeling analysis, and general principles from the literature to roughly estimate the magnitude of flows necessary to initiate geomorphic processes.

For all of the reasons discussed above, it is not possible to estimate future flow levels necessary to initiate geomorphic processes across an entire river, but for the purposes of this study, a rough estimate will be sufficient to evaluate the feasibility of reoperating reservoir releases for the purpose of achieving geomorphic objectives. In this study, we have focused on the flows necessary to mobilize the gravel bedded reaches, because they are more relevant to salmon restoration and because they will also result in mobilization of the sand bedded reaches. For floodplain inundation, we have focused on the lowland floodplains because they can be inundated at lower flows with demonstrated fisheries benefits.

The geomorphic conceptual model in its most succinct form is that high flows exert sheer stress on and transport sediment over the many structural components of a river channel and floodplain (bed, banks, other exposed surfaces) causing them to change, erode, migrate, and otherwise respond in a qualitatively predictable manner.

The geomorphic conceptual model described below is based on inputs and outputs. Inputs into the model are in three categories: flow, topography, and sediment. The outputs of the model are physical functions that in turn support habitat and biotic responses in the river system.

The Sacramento River requires a variety of high flows ($Q_{1.5} – Q_{10}$) to clean sediment, rejuvenate alternate bar sequences, prepare the floodplain for vegetation recruitment, and drive channel migration. Each one of these functions supports a biotic or habitat response described previously in this chapter.

Figure 1 illustrates the relationships between flow, sediment, and topographic inputs, and ensuing geomorphic processes. The model has been simplified to focus primarily on restoration objectives of this project and the inputs we propose to modify to achieve these restoration objectives (outlined in bold).

Inputs

The driving inputs in the conceptual model fall into three categories: flow, topography, and sediment. In reality, the conceptual model is at least partly cyclic, where the outputs are also inputs into successive cycles.

Flow Inputs

Flow inputs can be divided into three broad categories: regulated runoff, unregulated runoff, and groundwater inputs. Regulated runoff refers to flow releases from reservoirs over which humans exert some control. This is of particular importance to this conceptual model because it is the input we propose to modify. Unregulated runoff refers to flow inputs on streams and rivers over which humans do not exert much control. As the distance between any point on a river and an upstream dam or diversion increases, so too does the influence of unregulated runoff. More tributaries enter the river and the unregulated drainage area increases downstream from the dam or diversion.

Groundwater refers to any inputs from subsurface flows. These are not, in fact, entirely independent of regulated or unregulated runoff. Interaction of high flows with floodplain surfaces, flow durations, and flow frequencies impact the quantity and timing of groundwater inputs. Similarly, groundwater inputs impact base flow levels in both regulated and unregulated systems. For the sake of simplicity and focus, groundwater is considered an independent input.

Topographic Inputs

The shape of the river channel and floodplain, the location of the levees, the amount and type of vegetation in the channel and on the floodplain, and other structural characteristics comprise the topographical inputs of the conceptual model. They determine the distribution and velocity of any given flow quantity. For example, if one hundred acre-feet of water enter into a river, the water will pass much more quickly and smoothly if the river channel resembles a pipe - smooth and straight. If the channel is small, the water may spill onto the floodplain. If the channel is flat and wide, the water may travel very slowly. If the channel is full of vegetation, it may impede the flow of water or concentrate it between walls of vegetation.

Upstream Sediment Inputs

Upstream sediment inputs refer to silts, sands, cobbles, gravels or boulders transported in the river system. The quantity and quality of upstream sediment input create the building blocks for depositional processes. Because dams capture most upstream sediment, in regulated rivers sediment inputs are mostly from unregulated tributaries and storage in banks and bars below the reservoir.

Flow Outputs

Regulated flow, unregulated flow, and groundwater establish the amount of water in a river system. The topographic features determine the surface over which the water flows, and how it flows over that surface. Together, they determine the discharge, stage, and velocity of the flows (producing sheer stress). Combined with the frequency of these flows, and the upstream sediment inputs, they drive various geomorphic processes in river systems (described below).

Process Responses

Gravel Bed Mobilization

Gravel bed mobilization refers to the entrainment of D50[1] gravels. This generally occurs in alluvial rivers during the historic annual or biannual floods or roughly the $Q_{1.5}$ flow or Q_2. The mobilization of the gravels "cleans" them by removing accumulated silt, algae and other fine particulates (Stillwater Sciences, 2001).

Floodplain Inundation

Floodplain inundation is a hydrogeomorphic process that serves important ecological functions. Floodplain inundation provides temporary access to floodplain habitat for aquatic species, recruits nutrients from the floodplain into the river, and helps to recharge groundwater levels in riparian zones. Inundated floodplains provide important spawning and rearing habitat for numerous species. Sacramento splittail are largely dependent on inundated floodplains for successful spawning and rearing. Juvenile salmon grow two to three times as fast on floodplains compared to channels. Due to large surface area, the volume of area in the photo zone, and relatively warm temperatures during cool winter and early spring months, floodplains generate larges amounts of phytoplankton and zooplankton during the critical spring months.

Determining the flow necessary to inundate floodplains is complicated by the fact that different types of rivers and river reaches overflow their banks at different flows. Floodplain inundation in gravel bedded streams generally occurs during flows at or above the historic biannual flood (Q_2) (Stillwater Sciences, 2001). However, floodplain inundation on lowland Rivers such as the lower Sacramento and Feather Rivers occurr far more often, creating extensive flood basins that were inundated for weeks or months in all but the driest years (Bay Institute, 1998). Even under post dam hydrology, many of these basins, such as the Yolo Bypass, would flood for weeks or days at flows far below the bankfull discharge.

It is not realistic to restore floodplain inundation to the historic flood basins of the Sacramento Valley. It would simply be too disruptive to the water supply and economic functions of the Sacramento River and its historical floodplains. It is, however, more realistic to intentionally inundate the system of flood bypasses designed to safely accommodate flood flows in the Sacramento River. The magnitude of flows necessary to inundate bypasses, as well as the frequency of bypass inundation is controlled by weirs at the upstream end of each bypass. Water does not enter the bypass and create inundated habitat until the river stage is high enough to overtop the weir. A study sponsored by the US Army Corps of Engineers, however, demonstrated that it is possible to inundate the bypasses at greater frequency and lower flows by intentionally notching the weirs (NHI, 2002). For the purposes of this study, we have assumed that you could inundate

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[1] D refers to the length of the intermediate axis of gravels in a gravel bed. The D50 refers to the gravels in the 50th percentile size class, relative to the other gravels in the bed.

floodplains in flood bypass areas using this method at multiple weirs in the Sacramento Valley.

Bed Scour and Deposition

Bed scour and deposition refer to the removal of sediment and the corresponding replacement of sediment that occurs during storm events. The bed scour and deposition process discourages the river channel from being "fossilized" by riparian encroachment, maintaining it in a dynamic alluvial state. It is a greater level of mobilization than simply gravel bed mobilization, in that the bed degrades during the ascending limb of the hydrograph and aggrades on the receding limb of the hydrograph. Q_5 to Q_{10} floods generally provide the necessary shear stress to scour beds and redeposit with little net change in channel elevation (Trush et al. 2000)

Floodplain Sediment Scour and Deposition

Floodplain sediment scour requires greater sheer stress than simply inundation and generally occurs during flows equivalent to the historic Q_{10}. By exerting sheer stress, scour prepares floodplain surfaces for recruitment of riparian vegetation by removing existing vegetation, depositing clean sand and transporting new seed across the floodplain. Depositional processes also require higher flows to transport sediment away from the channel onto the floodplain. As flows increase, they spill across the floodplain, velocities slow, and the river deposits its sediments. Most floodplain sediments are the result of this process (Leopold et al., 1964). Deposition on the floodplain further reshapes and prepares the surfaces for recruitment.

Channel Migration

Channel migration is a function of stream energy and substrate strength. By eroding, channel migration recruits gravels and large woody debris into the system and directly and indirectly creates habitat complexity in the channel and floodplain. By depositing, channel migration prepares surfaces for pioneer species allowing for a diversity of riparian habitats. The process of channel migration is responsible backwater areas, sloughs, oxbow lakes, and secondary or abandoned channels (Bay Institute, 1998).

Channel migration requires the greatest amount of stream energy and generally requires large flows for a prolonged period, which can require very large volumes of water. Flows larger than the bank full discharge may be necessary to cause major channel migration or channel avulsion, but gradual channel migration may occur each year at some bends with flows well below the bank full discharge.

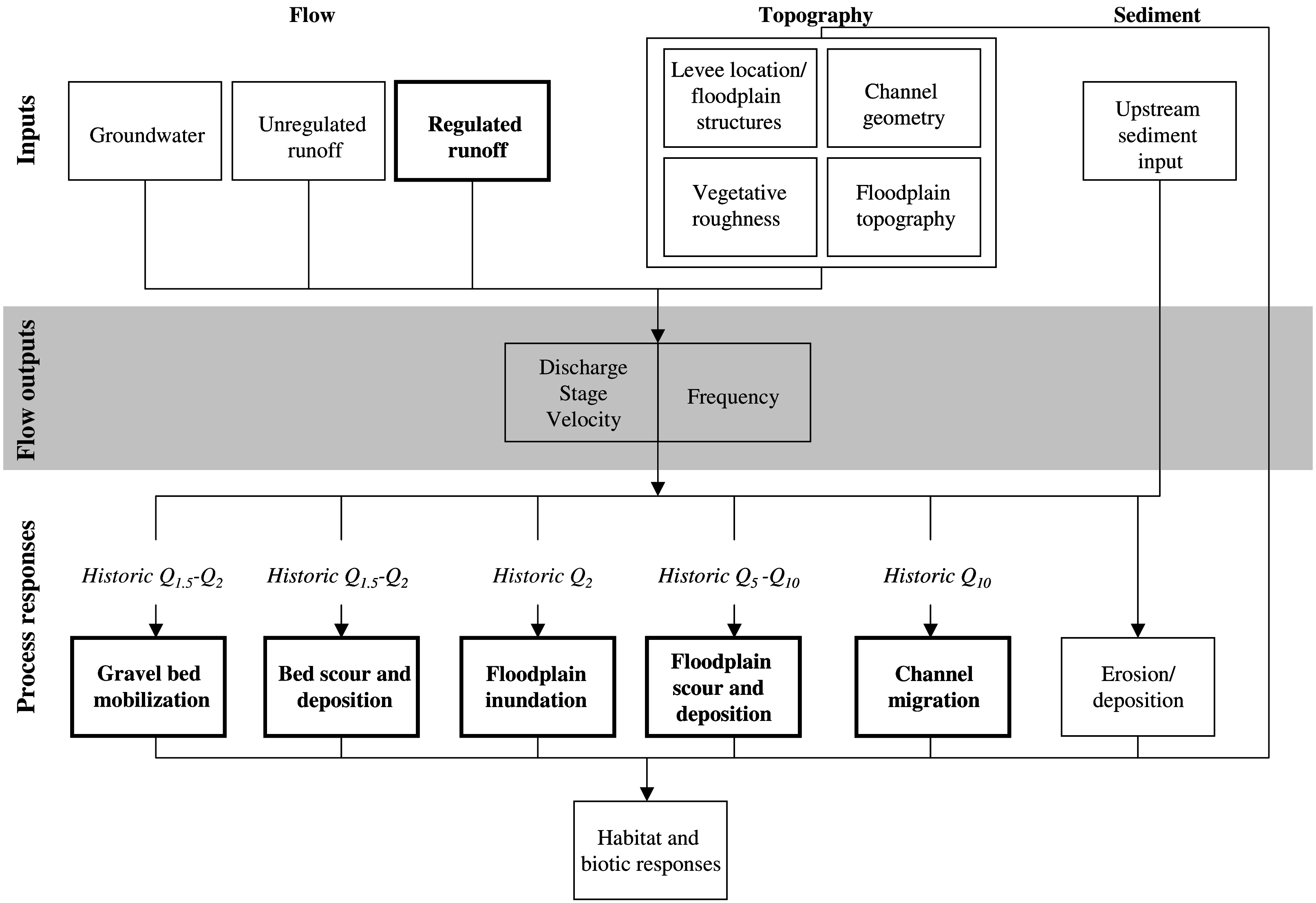


Figure 1. Geomorphic Conceptual Model. The figure above illustrates the relationships between flow, sediment, and topographic inputs, and ensuing geomorphic processes. The model has been simplified to focus primarily on restoration objectives of this project and the inputs we propose to modify to achieve these restoration objectives (outlined in bold).

Appendix C: Cottonwood Conceptual Model

4.2 Cottonwood Conceptual Model

Critical life history stages of cottonwoods and other pioneer riparian species in the Sacramento River basin are tightly linked with the hydrologic and geomorphic processes described in the previous conceptual model. Floodplain scour/deposition, channel migration, channel avulsion, and erosion/deposition processes generate new sites for cottonwood seedling establishment. Floodplain inundation provides moist substrates to sustain seedlings through their first growing season. Gravel and sand bed mobilization and bed scour/deposition help define a minimum elevation for cottonwood recruitment. Over time, these processes play a key role in determining the distribution, extent, and age structure of cottonwood communities in the Sacramento River basin. In turn, as cottonwoods mature, they have the potential to impact sediment deposition processes, channel stability, and channel dynamics. Both geomorphic processes and riparian habitat structure are important determinants of abundance and distribution of aquatic species such as chinook salmon, as described in the next section.

Land use activities and managed flow operations have greatly reduced the extent and integrity of riparian forests, particularly cottonwood forests, in the Sacramento Basin. Most existing cottonwood stands in the basin are mature, exhibiting older age structure than typical under natural conditions (McBain and Trush 2000, Stillwater Sciences 2002a, Jones & Stokes 1998). The absence of sapling cohorts in many reaches of the basin suggests that natural recruitment processes are not occurring under current conditions (McBain and Trush 2000, Jones & Stokes 1998, Stillwater Sciences 2002a). Without younger age classes, senescent trees cannot be replaced as they die, potentially leading to further substantial loss of this once dominant riparian vegetation community.

This conceptual model describes the ecological flows and geomorphic processes that drive establishment and recruitment of cottonwoods under natural conditions (Figure 2). The model identifies factors that currently limit cottonwood recruitment in the Sacramento Basin and opportunities for restoring this process through modification of flows and/or channel-floodplain geomorphology. Because channel attributes may differ widely among rivers and reaches of the Sacramento Basin, flow characteristics for restoration are described qualitatively in this model, with respect to channel and floodplain elevations.

Various species of cottonwoods share the characteristics discussed below. Any discussion specific to the Fremont cottonwood *(Populus fremontii),* the predominant species of the Central Valley (Stillwater Sciences 2002a, 2002b, 2006: McBain and Trush 2000), is noted as such.

4.2.1 Site Preparation

The creation of barren nursery sites through erosional and depositional processes is the first step in cottonwood seedling recruitment. Because cottonwood seeds contain very little endosperm, seedlings require full sunlight to produce photosynthates for growth and development; thus, cottonwood seedlings compete poorly on vegetated sites (Fenner et al. 1984). Under natural flow regimes, moderate 5- to 10-year flood events precipitate channel migration and the creation of point bars suitable for cottonwood seedling establishment (McBain and Trush 2000, Trush et al. 2000). Large flows scour away herbaceous plants and/or deposit fine sediments on floodplains, preparing new seed beds for pioneer riparian species (Mahoney and Rood 1998). In addition to point bars and floodplains, cottonwood forests may occur in high flow scour channels, oxbows, and other off-channel backwaters that receive scouring and sediment deposition (Stillwater Sciences 2002a).

Over the past century, continued agricultural and urban encroachment into riparian zones have greatly decreased the landscape area upon which cottonwood recruitment can occur (Stillwater, 2006; McBain and Trush 2000, Jones & Stokes 1998). In addition, flow regulation has reduced the intensity and frequency of winter and spring flood flows. The lower flows have led to a moderate reduction in the high-energy processes that, in less regulated river systems, create new seedbeds for recruitment—channel migration, point bar accretion, bed scour, and floodplain inundation. Levees and bank stabilization practices have reduced floodplain width and channel migration, in addition to isolating riparian backwaters (Stillwater, 2006). In addition, the loss of upstream sediment supply may have resulted in channel incision, requiring greater discharges for flows to inundate adjacent floodplains (TNC, 2003). The cumulative result of these processes has been a significant reduction in favorable germination sites for cottonwood seedlings.

There are several options for human intervention to increase availability of suitable recruitment sites for cottonwoods. Flood operations can be modified in wet years to allow shorter duration, but higher winter or spring peak flows sufficient to inundate floodplains and mobilize channel sediments (Jones & Stokes 1998). Reservoirs can be operated to release flows that mimic the 5- to 10-year flood events historically associated with cottonwood recruitment. Mechanical approaches include lowering floodplain surfaces for greater inundation frequency at current low flows, setting back or breaching levees to increase floodplain area, restoring the river's connection with abandoned side channels and backwaters, and artificially clearing floodplain sites to reduce plant competition.

Reductions in peak flows can lead to vegetation encroachment of more aggressive native riparian species into the formerly active river channel, further limiting cottonwood recruitment (Jones & Stokes 1998). Under natural hydrologic conditions, surfaces at the edge of low-flow channels were high-scour zones that generally prohibited the establishment of riparian vegetation. Under regulated conditions where the frequency of scouring flows has decreased significantly, vegetation —primarily alders and willows and forbes— can encroach along channel margins that were previously characterized by shifting and exposed gravel or sand bars (Stillwater Sciences 2002a, McBain and Trush 2000, FWUA and NRDC 2002). Vegetation encroachment can ultimately result in simplified and confined river channels resistant to fluvial geomorphic processes (e.g., channel migration) that create barren seedbeds for cottonwood recruitment. This does not appear to be a problem on the Sacramento River due to relatively frequent high flow events, but vegetation studies do indicate that recruitment is currently dominated by willows (TNC, 2003) to the potential detriment of cottonwoods. Therefore, maintaining the proper frequency and magnitude of high flows is necessary for maintaining habitats where cottonwoods are likely to become established and dominant.

4.2.2 Seedling Establishment

Establishment describes the process of seed release, germination, and growth through the end of the first year. This stage in the life cycle of cottonwoods is marked by high mortality rates, in both natural and regulated river systems (Mahoney and Rood 1998).

Most studies on Fremont cottonwood recruitment have focused on establishment of new stands through seed release, rather than vegetative sprouts. In the Sacramento Basin, mature female Fremont cottonwoods release hundreds of thousands to millions of seeds between April and June. Timing and duration of seed release are influenced by photoperiod and temperature, with maximal seed release generally occurring over a three-week period (FWUA and NRDC 2002, Stillwater Sciences 2002a). Seeds are dispersed by wind and water. They may travel up to a couple miles away, but more often they are deposited within a several hundred feet of the parent tree (Braatne et al. 1996). Dry Fremont cottonwood seeds are viable for one to three weeks (Horton et al. 1960). Once they are wet, their viability decreases to a few days (Braatne et al. 1996). Thus, for riparian restoration purposes it is important to understand the mechanisms that influence cottonwood seed release and dispersal, to ensure that timing of spring (snow-melt) pulse flows coincides with cottonwood seed dispersal. The spring pulse flows provide the moist nursery sites necessary for immediate germination of seeds (Mahoney and Rood 1998).

Cottonwoods germinate within 24–48 hours of landing on bare, moist substrates such as silt, sand, or gravel (John Stella, Stillwater Sciences, pers. com., 8 April 2003). For one to three weeks after germination, the upper layer of substrate must maintain moisture as the seedlings' root systems grow. Post-germination decline of river stage, which is presumed to control adjacent groundwater levels (JSA and MEI 2002), should not exceed approximately one inch per day (Mahoney and Rood 1998, Busch et al. 1992). This is the rate at which seedling root growth (0.16–0.47 inches/day; Reichenbacher 1984, Horton et al. 1960) can maintain contact with the capillary fringe of a receding water table in a sandy substrate. Cottonwood root growth and seedling establishment rates are higher in these soils than in coarser textured soils, which are more porous (Kocsis et al. 1991). In reaches with gravelly substrates, slower draw-down rates are necessary to support seedling establishment.

Mahoney and Rood (1998) describe the temporal and spatial window of opportunity for cottonwood seedling establishment as a "recruitment box", defined by timing of spring pulse ("establishment") flows/seed release and by seedling elevation relative to river stage. Optimal timing of seed release for successful establishment is during the gradually declining limb of a spring pulse flow. Optimal elevation relative to river stage is set at the upper end by the seedling's ability to maintain contact with the declining water table, and at the lower end by scouring and inundation flow levels in the first year, especially during the first winter.

The vast majority of cottonwood seedlings in this life stage die of drought stress because root growth is unable to keep pace with the decline in the water table (Mahoney and Rood 1998). Regulated ramp-down rates after spring pulse flows are often steep, in order to conserve water for human uses (Stillwater Sciences 2002b). Alternatively, decreased spring flows in regulated systems may cause seedlings to initiate at elevations too low to protect seedlings from flooding and scouring flows later in the growing season or during the winter (Mahoney and Rood 1998). In some rivers overwinter mortality of cottonwood seedlings is particularly high because flow regulation has reduced spring peak flows relative to winter peak flows (Stillwater Sciences 2002a).

High seedling mortality rates suggest that opportunities for improving cottonwood recruitment may be greatest in this life stage. In the first year of life, drought stress can be minimized by managing flood release flows for slow ramp-down rates after 5- to 10-year flood releases. Since reservoir spills often occur in wet years, reduced ramp-down rates may be accomplished by reshaping existing flood release flows without reducing water supply deliveries.

Artificial floodplain irrigation, either through flooding or a drip system, can also relieve summer drought stress for newly initiated seedlings. Agricultural irrigation close to the channel during the dry season would achieve similar gains in groundwater level. Grazing and trampling of seedlings by livestock can be minimized through grazing management practices or by building exclosures to protect cottonwood nurseries. To reduce winter mortality due to scouring and inundation, establishment flows can be discharged in spring rather than winter.

4.2.3 Vegetative Reproduction

In addition to seed dispersal and seedling establishment, vegetative reproduction is a potentially significant but commonly overlooked method for cottonwood recruitment along newly formed or previously established floodplains and point bars. Fremont cottonwoods can reproduce clonally through sprouting of buried broken or detached branches, or through development of suckers from shallow roots. This little-studied phenomenon has been alluded to in the riparian literature, and reported anecdotally and in unpublished studies (Tu 2000; Mike Roberts, TNC, pers. com., 27 February 2003). Additional insight into the process can be gained from studies of vegetative reproduction in other cottonwood species (Rood et al. 1994, Reed 1995).

Vegetative reproduction may be particularly important for sustaining Fremont cottonwood populations in altered hydrologic systems such as the Sacramento Basin. Tu (2000) reported that three years after the floods of 1996 established a new sandbar along the lower Cosumnes River, successful Fremont cottonwood recruits from vegetative branches outnumbered those from seeds by almost six to one. This is especially notable in light of the fact that the original 1996 cohort studied included 7,898 Fremont cottonwood seedlings compared to only 36 vegetative branches. Thus, the greater number of surviving 3-year-old recruits from vegetative branches compared to seedlings was due to their considerably higher survival rates rather than initial predominance. Most of the seedlings in this study died in their first year post-germination as a result of desiccation. Tu (2000) surmised that vegetative branches were better able to survive the critical first year by virtue of their greater nutrient storage, higher competitive ability for light, and greater proximity to declining water tables (most were partially buried in the soil).

In many parts of the Sacramento Basin, it is possible that the loss of natural recruitment processes under current conditions has increased the importance of vegetative propagation relative to seed propagation for sustaining cottonwood populations. An intervention opportunity based on natural vegetative reproduction is to plant cuttings collected from local cottonwood populations. Although this option would be time and labor intensive, cottonwoods have been successfully re-established by this method in Clear Creek and on the Sacramento and Merced Rivers (Mike Harris, USFWS, pers. com., 26 February 2003; John Stella, Stillwater Sciences, pers. com., 8 April 2003). Once a small number of individuals are successfully recruited to a new site, expansion of the population may subsequently occur via sprouting, suckering, or seed dispersal. Due to the uncertainties of seed dispersal timing, availability of flows, and high cost of flows (unless part of flood release flows), a dual strategy of vegetative reproduction and improved flow management may be the most cost effective option for improving rates of cottonwood recruitment in the Sacramento Basin.

4.2.4 Recruitment

The recruitment phase occurs from the end of the first year to sexual maturity, at five to ten years of age for Fremont cottonwoods (Reichenbacher 1984). Flow-related mortality is relatively low during this period because a plant has generally developed a sufficient root and shoot system to survive seasonal conditions of drought and flooding. Growth rates are very high in the second year, by the end of which roots may be almost ten feet deep (Ware and Penfound 1949). After the second year, growth rates level. Despite extensive root development during this stage, cottonwoods are still somewhat susceptible to drought stress. Thus, yearly flows must be sufficient to maintain groundwater levels within 10 to 20 feet of ground surface elevations (JSA and MEI 2002).

Groundwater extraction and reduced flows can reduce groundwater levels and induce drought stress in cottonwood saplings (Jones & Stokes 1998). In regulated river systems, low frequency of scouring flows may also allow exotics such as eucalyptus, tamarisk, and giant reed to establish and outcompete early successional native species such as cottonwood (Jones & Stokes 1998, McBain and Trush 2000). Relatively low flow-related mortality during this stage diminishes the importance of flow management opportunities. However, mortality due to herbivory (e.g., beavers, voles, mice) may be significant during this phase (John Stella, Stillwater Sciences, pers. com., 8 April 2003). Density-dependent mortality (self-thinning) may also occur if initial seedling density is high.

4.2.5 Maturity & Senescence

Maturity begins with the first flowering of a sexually mature adult. Senescence begins when reproductive capacity declines. Field studies indicate that a large proportion of existing cottonwood stands in the Sacramento Basin comprise mature and senescing individuals (McBain and Trush 2000, Stillwater Sciences 2002a, Jones & Stokes 1998). As these cottonwoods die (lifespan >130 years; Shanfield 1983), they are unlikely to be replaced by new generations of cottonwoods. Although cottonwood seedlings are readily germinating on the Sacramento River, most cohorts are not surviving to reproductive maturity, for the reasons outlined above. In addition, urban and agricultural conversion of mature cottonwood forests in the Sacramento Basin further reduces seed sources and threatens future prospects for this once-abundant riparian habitat (McBain and Trush 2000, Jones & Stokes 1998, Stillwater Sciences 2002a).

Cottonwood Conceptual Model

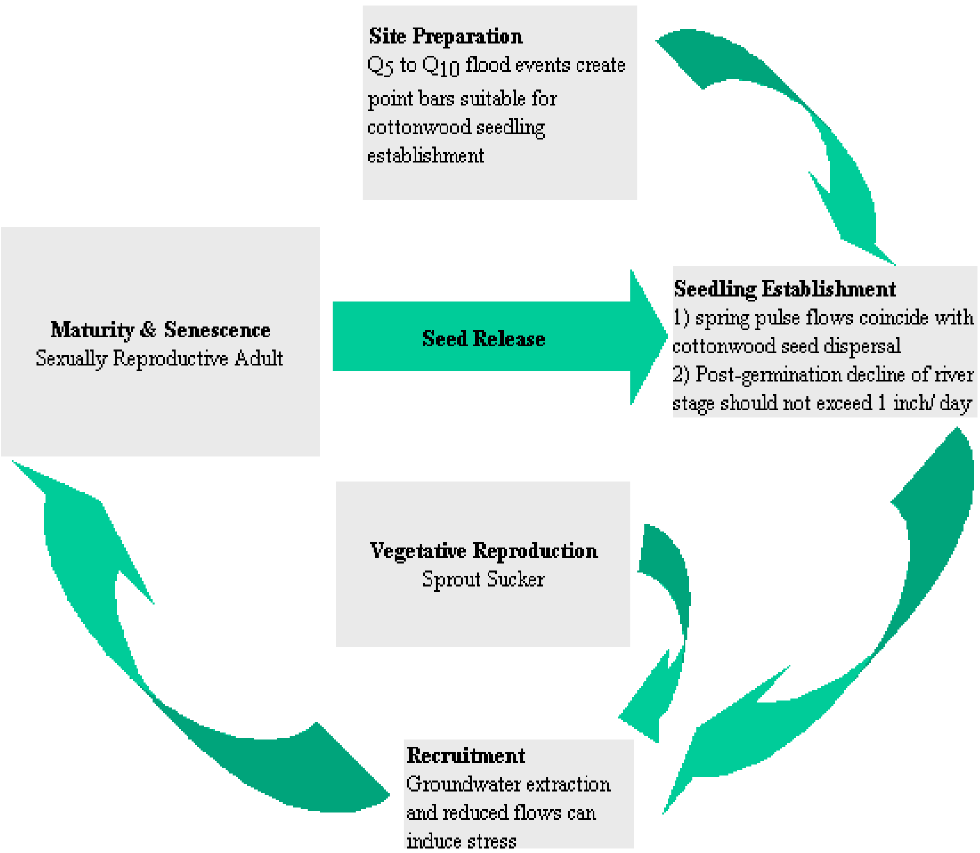
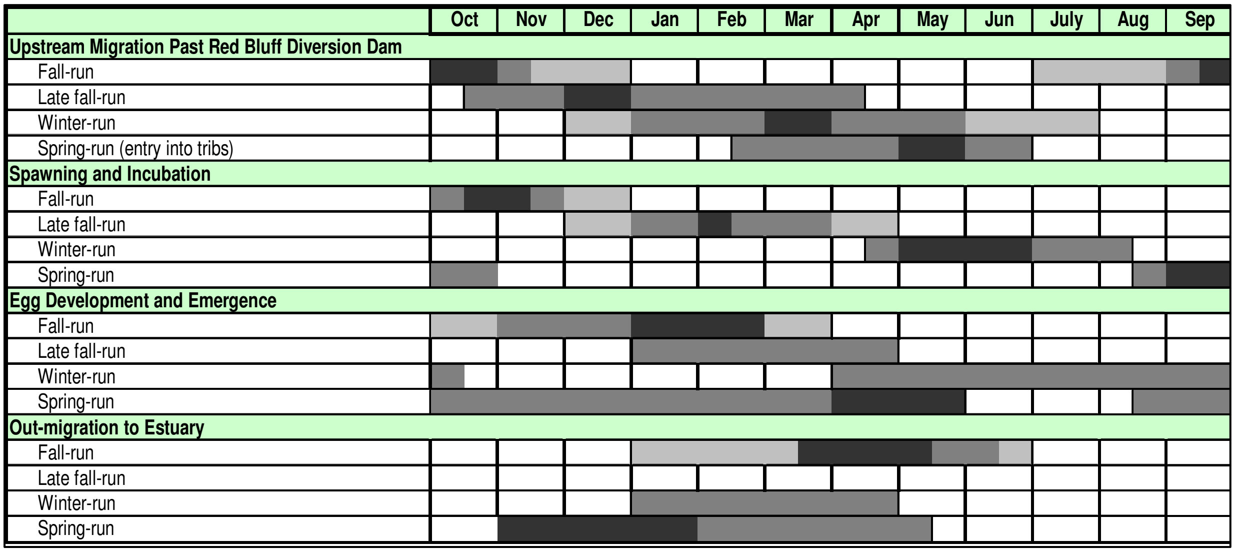


Figure 2. Cottonwood Conceptual Model for Sacramento Basin highlights characteristics of the flow regime that effect different life stages.

Chinook Salmon Conceptual Model

This conceptual model focuses on the flow related factors that affect populations of Chinook in the Sacramento and Feather Rivers. There are many non-flow factors that affect salmon populations, but we have only focused on the flow related factors for the purpose of developing an environmental flow regime. The model addresses flow-related factors for four runs of Chinook salmon and steelhead by life stage.

There are four distinct runs of Chinook salmon in the Sacramento River, the fall-run, the late fall-run, winter-run and spring-run. The different runs of Chinook differ in the timing of their life history. In general each run is named for the time that it begins migrating back to its natal stream. Table 1 shows that each run has the same life stages, but different runs move through the life-cycle at different times of the year and often employ different life stage strategies. For example, fall-run salmon are sometimes referred to as ocean type because they generally migrate to the ocean before their first year, while spring run generally spend a full year in the stream before migrating. Differences in timing and life history strategies mean that different runs can be vulnerable to different stressors. For example, winter run eggs incubate over the summer months and are therefore limited by summer water temperatures, while fall run eggs are much less likely to endure temperature stress since they incubate during the relatively cool winter months. The Chinook Conceptual Model lists the limiting factors that may impact the success of each life stage, the degree to which the limiting factor is relevant may depend on the particular run of Chinook which is being considered.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep
Upstream Migration Past Red Bluff Diversion Dam												
Fall-run	█	▒░	░							░	░	▒█
Late fall-run	□▒	▒	█	▒	▒	▒	▒□					
Winter-run			░	▒	▒	█	▒	▒	░	░		
Spring-run (entry into tribs)					□▒	▒	▒	█	▒			
Spawning and Incubation												
Fall-run	▒█	█▒	░									
Late fall-run			░	▒	█▒	▒	░					
Winter-run							□▒	█	█	▒	▒□	
Spring-run	▒										□▒	█
Egg Development and Emergence												
Fall-run	░	▒	▒	█	█	░						
Late fall-run				▒	▒	▒	▒					
Winter-run	▒□						▒	▒	▒	▒	▒	▒
Spring-run	▒	▒	▒	▒	▒	▒	█	█			□▒	▒
Out-migration to Estuary												
Fall-run				░	░	░█	█	█▒	▒░			
Late fall-run												
Winter-run				▒	▒	▒	▒					
Spring-run		█	█	█	▒	▒	▒	▒□				

Table 1: Salmon life history table. The timing and duration of the life history stage for each of the salmon runs; These are the periods of time that are most critical to the success of a particular life stage.

░	Period of light activity
▒	Period of acitivity
█	Period of peak activity

Table 2: Chinook Salmon (CHS) Thermal Tolerances. All lethal temperature data is presented as incipient upper lethal temperatures (IULT), which is a better indicator of natural conditions because experimental designs use a slower rate of change (1oC/d). (Modified from Moyle 2005, information largely from McCullough 1999.)

	Sub-Optimal	Optimal	Sub-Optimal	Lethal	Notes
Adult Migration	<10°C	10-20°C	20-21°C	21-24°C	Migration usually stops when temps climb above 21°C. Under most conditions fish observed moving at high temps are probably moving to refugia.
Adult Holding	<10°C	10-16°C	16-21°C	10-20°C	Fish in Butte Creek experience heavy mortality above 21°C but will survive temperatures as high as 23.5°C for short periods of time. In some holding areas fish have been observed in temperatures of 20°C for over 50 days during the summer.
Adult Spawning	<13°C	13-16°C	16-19°C	10-20°C	Egg viability may be reduced at higher temperatures
Egg Incubation	<19°C	9-13°C	13-17°C	10-20$_{o}$C	This is the most temperature sensitive phase of life cycle American River CHS experience 100% mortality in temperatures greater than 16.7°C; Sacramento River fall-run CHS mortality exceeded 82% in temperatures greater than 13.9°C
Juvenile Rearing	<13°C	13-20°C	20-24°C	10-20$_{o}$C	Past exposure (acclimation temperatures) has a large effect on tolerance. Fish with high acclimation temps may survive at 28-29°C for short periods of time. When food is abundant, fish that live under conditions between 16 and 24°C may grow very rapidly.
Smoltification	<10°C	10-19°C	19-24°C	10-20$_{o}$C	Smolts may survive and grow at suboptimal temps but are primarily avoiding predators

Temperature is one of the key factors that can limit salmon population numbers, but different life-stages display widely different temperature tolerances (Table 2). In general, salmon are most vulnerable to temperature stress in the egg life stage and least vulnerable in the juvenile life stage. Winter run are acutely sensitive to temperature, because their eggs are present during the summer months. Thus, different runs are effected differently by temperature stress due to the differences in run timing.

4.2.6 Life in the Ocean

All four runs of Chinook salmon spend approximately 1 to 5 years in the ocean before returning to spawn in their natal stream (Moyle, 2002), though historically, most Chinook salmon returning to the Sacramento River are approximately 4 years old (Clark 1929, in USFWS 1995).

Mortality of salmon in the ocean is based on natural and non-natural factors. Natural stressors include predation by other species, and ocean conditions, such as nutrient flow patterns (CMARP and CALFED Appendix C). The non-natural mortality factor affecting salmon is harvest. From 1967 to 1991, 60-80% of total salmon production was harvested (CMARP).

Changes in river management will do little to decrease natural mortality of salmon in the ocean. This study is not considering restoration of Chinook populations by limiting ocean harvest of salmon at this time. However, it is important to emphasize that large-scale harvesting of salmon in the ocean may be severely limiting salmon populations. If we could manage ocean stocks to increase the number of older fish, it may be possible to increase the ecosystem resilience against drought.

4.2.7 Adult Upstream Migration

Adult salmon migration can be limited by high temperatures and low dissolved oxygen. In the Sacramento River where flows are severely limited, adult salmon migration are delayed or disrupted by low flows and poor water quality. In particular, low levels of dissolved oxygen (DO) during summer and early fall at the Stockton Deep Water Ship Channel and high levels of ammonia from the Stockton wastewater plant in October cause poor water quality to delay adult Chinook migration up the lower San Joaquin, which causes an increase in poaching, lower egg and sperm viability and greater threats to outmigrating juveniles (Hallock et al, 1970 in CMARP). Fish migration does not appear to be limited by existing flow conditions, but reduced flows combined with polluted or warm water agricultural discharges could create problems for migrating fish.

Fall-Run

Adult fall-run Chinook salmon migrate into the Sacramento River and its tributaries from June through December (Yoshiyama, et al. 1998) Migration Peaks in September and October and spawning by mature adults begins shortly thereafter. Cool water releases in the Sacramento and Feather rivers are unnaturally high in late-summer and fall due to hypolimnetic discharge from

Shasta Reservoir (Stillwater, 2006). Increased summer and fall discharge, therefore may improve water quality and temperature conditions for migrating fall-run salmon. High ambient temperatures during late summer and early fall combined with warm or polluted agricultural drain water could become a problem for migrating salmon at lower stream flows (Domagalski, et al.). By mid October, however, water and ambient temperatures are cool enough for migrating salmon (Figure 4).

High water temperatures can prevent upstream migration, and can cause physiological damage and exhaustion (CALFED C-9). Temperatures above 70°F (21.1°C) prevented the upstream migration of adult Chinook salmon from the Delta to the Sacramento River, but the Chinook began migrating into the lower Sacramento as water temperatures fell from 72°F-66°F (22°C-18.9°C) (Hallock 1970 in USFWS, 1995). Temperatures ranging between 50°F and 67°F were found to be suitable for upstream migration of fall-run Chinook (Bell, 1986; Bell, 1973 in USFWS, 1995; and Bell, 1991 in Oroville). Although water temperatures below 38°F are reported to decreases adult survival (Hinze 1959 in USFWS, 1995), temperatures this low are not likely to occur in the Sacramento Basin tributaries.

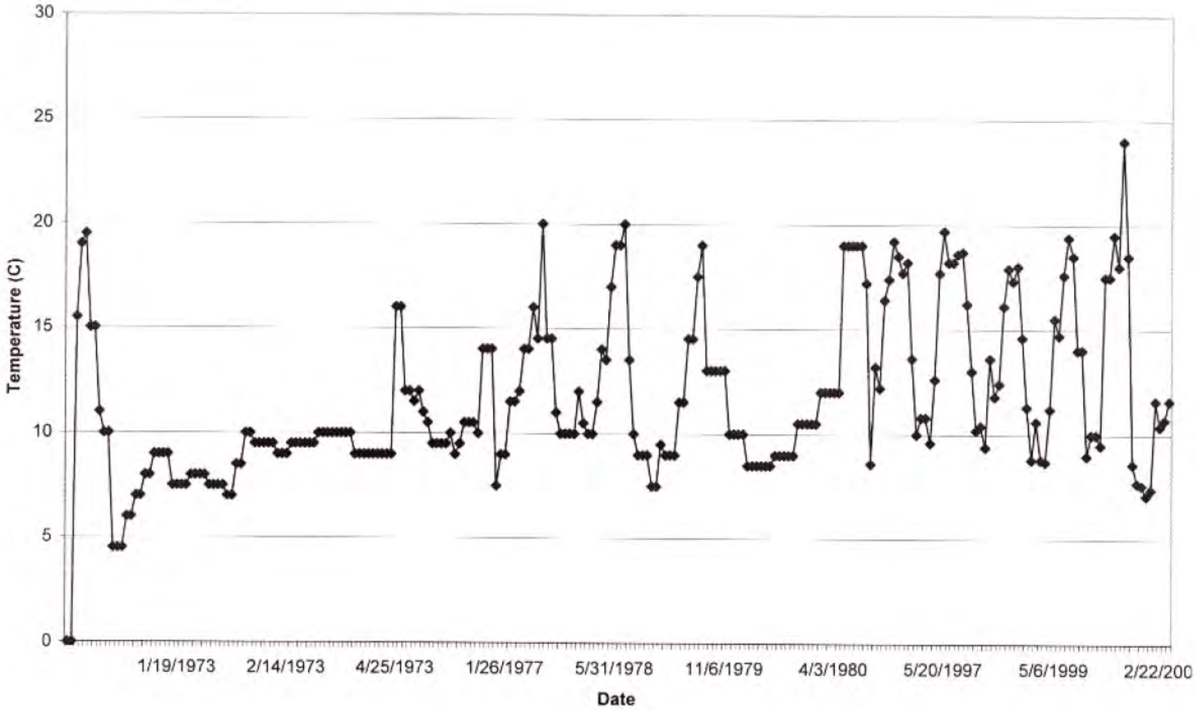


Figure 3: Temperature data collected on the Sacramento River downstream of Wilkins Slough (RM 118) between 1973 and 2000 at the Wilkins Slough gaging station (#11390500). Modified from Figure 4.2-7 in the Sacramento River Ecological Flows Study State of the System Public Review Draft.

A more natural flow regime in the late summer and fall could delay or impede the migration of fall-run salmon. Observations from the San Joaquin Basin where fall flows are lower and warmer suggest that the peak of the fall-run migration would shift to October and November. This may not reduce the overall population of fall-run salmon spawners, but it could create problems for recruitment by delaying emergence until the later spring months. Based on experience from the San Joaquin River (Stillwater, 2003) fall-run that emerge latter may have difficulty migrating out of the Sacramento and Feather Rivers before temperatures begin to rise in the late spring.

Increasing instream flows in the early fall in the Sacramento basin could improve conditions for migrating adult fall-run Chinook by reducing straying, improving water quality, improving passage barriers, decreasing water temperatures and decreasing the delay in migration. If salmon migration is motivated by major storms, early freshets or pulses after the first rain, and most of the large flows from storm events are trapped behind dams, reservoir operators can simulate pulse events by releasing water from the reservoir. However, “There is [a] concern that pulse flow releases in mid October to attract salmon may cause the fish to enter the rivers earlier than normal, which may expose them to high water temperatures when the pulse flows cease.” (CMARP). Therefore, if flows are increased during this mid-fall period, it is important to continue to maintain adequate flows for migrating adults and subsequent spawning.

Late-Fall Run

Adult late fall-run Chinook salmon migrate up the Sacramento River between mid-October and mid April, with peak migration occurring in December (Vogel and Marine, 1991). Water temperature and flow conditions within the natural range of variability will be suitable for late fall-run since water temperatures are within optimal levels.

Winter-Run

Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Van Woert 1958, Hallowck et al. 1957 in NMFS 1997). Migration past Red Bluff Diversion Dam begins in mid-December and can continue into early August but the majority of winter run adults migrate past Red Bluff Diversion Dam between January and May with a peak in mid-March (Hallock and Fisher, 1985). Current RBDD operations facilitate upstream passage of winter-run adults by raising gates between September 15 and May 15.

Lower fall and winter flows are unlikely to create temperature adverse to winter-run migration, but lower spring flows could conceivably become a problem in drier years if spring flows are further reduced. Similarly, increased spring flows could be beneficial particularly for the latter part of the migration, but there is no evidence that the current adult migration is stressed by low flows or high temperatures.

Spring-Run

Although spring-run were probably the most abundant run historically in the Sacramento River (Mills and Fischer, 1994), most spring-run fish currently spawn in three tributaries: Deer, Mill, and Butte Creeks. Mainstem habitat was mostly blocked by Shasta Dam, but some spring-run still spawn below the dam, although they have apparently hybridized to some extent with the fall-run (Stillwater, 2006).

Adult spring-run enter the Sacramento-San Joaquin Delta beginning in January, entering their natal spawning streams from March to July (Myers et al. 1998). Adult spring-run migrate upstream to spawn in different tributaries at somewhat different times, suggesting some degree of life-stage flexibility. Butte Creek fish migrate up beginning in February and peaking March and April when flows peak in that stream. Adults from Deer and Mill Creek begin migration in March and peak in May, concluding in June.

Increased spring flows in the Sacramento during the late spring may provide some small benefits for migrating salmon in drier years, but there is no evidence that the adults are currently under stress during their migration. Increased flows in the Sacramento in drier years will not benefit conditions in the tributaries where most spring-run salmon migrate.

4.2.8 Spawning, Egg Incubation, and Emergence

Different runs spawn throughout the year and construct their redds in gravels that are typically 6 inches (15 cm) or less in diameter (Flosi et al., 1998). High water temperatures (greater than 56°F) due to low reservoir storage, high air temperatures and low flow releases could decrease available spawning habitat and affect sperm and egg viability. High temperatures cause spawners to concentrate in the upper reaches where water temperatures are lower, which increases the rate of superimpostion of redds (CMARP). “Mature females subjected to prolonged exposure to water temperatures above 60°F have poor survival rates and produce less viable eggs” (USFWS, 1995) and water temperatures below 38°F also can result in lower egg viability (Hinze 1959 in USFWS, 1995).

In order to provide quality areas of spawning habitat, adequate flows need to be released from dams into the tributaries during the spawning period. Over the long run, periodic high flows are necessary to mobilize gravels and flush-out fine sediments. However, large peak flow events that occur in channels that have been excessively incised and leveed cause excessive gravel mobilization, which can disrupt spawning and cause egg mortality (CMARP). Therefore, these flows should be released during periods when most fry have already emerged from the gravels so they reduce mortality to incubating salmon eggs (McBain and Trush, 2000).

Eggs usually incubate in the gravel for approximately 6 1-64 days before hatching (Healey 1991) and it takes about 70 days for fry to emerge from the gravel (USFWS 1998 in SP Cramer, 2000). This is consistent with EA Engineering’s findings, (1991 in CMARP) which found that eggs incubate for 40-60 days and remain in the gravel for 45-90 days. When fry first emerge from the gravel they are known as alevins and have an attached yolk sac that they depend on for food and nourishment.

The development of eggs into fry appears to be a difficult time for Chinook (Healey, 1991). High water temperatures, fine sediment capping, dewatered redds, poor quality gravel, and low substrate flow may contribute to the high mortality rate during egg and alevin development. High water temperatures (greater than 56°F), due to low reservoir storage, high air temperatures and low flow releases (CMARP, Loudermilk 1996) may cause egg mortality and decrease the incubation period when eggs are in the gravel (EA Engineering 1993 in CMARP). The late-fall and winter period of incubation combined with hypolimnetic discharge from the reservoirs generally maintains adequate water temperatures.

Low substrate flow through spawning gravels is known as an important cause of mortality in egg and alevin development. “Adequate water percolation through the spawning gravel is essential for egg and alevin survival. There is no doubt that percolation is affected by siltation and that siltation in spawning beds can cause high mortality” (Shaw and Maga 1943, Wickett 1954, and Shelton and Pollock 1966 in Healey 1991). Fine sediment capping occurs when redds become covered with fine silt (fines) due to small storm events that transport and deposit fines downstream. Shaw and Maga (1943) observed that siltation resulted in greatest mortality when it affected eggs in their early incubation stage (in Healey, 1991). Although common in steep coastal watersheds, fine sediment capping is relatively rare in the Sacramento basin due to sediment trapping in upstream reservoirs and the general lack of unregulated tributaries upstream of spawning areas.

Dewatering of redds is a known mortality factor effecting development of alevins. (Becker et al., 1982, 1983 in Healey, 1991). Dewatering of redds can be minimized below dams by careful flow regulation. Contaminated groundwater caused by seepage from agricultural or urban areas causes an increase in water temperature and reduces dissolved oxygen within spawning gravel, which may be harmful to incubating salmon eggs (CMARP).

Adequate base flows during the incubation and emergence period combined with periodic flushing flows outside the period should reduce the mortality factor of eggs and alevins. Instream flows, at or above spawning flows, should be maintained throughout the incubation and emergence period to avoid dewatering redds. Siltation and capping from fine sediments could be minimized with small reservoir releases timed to coincide with rainfall induced local run-off. These releases would help convey fine sediments out of the spawning reach.

Fall-Run, Late-Fall, and Spring Run

The mature adults spawn shortly after arriving at their spawning grounds between September and December. In the Sacramento and its tributaries, incubation and alevin development occurs from October through March (CMARP). Flow or temperature conditions are unlikely to be a problem except when Shasta Reservoir levels are drawn down. High water temperatures is probably not an important factor affecting fall, late fall and spring- run Chinook in the Sacramento Basin because incubation occurs between September and April when water temperatures do not rise above 14°C (57.2°F).

Winter-Run

Temperature stress induced by lower flows or lower reservoir levels in the summer, could be a significant problem for winter-run Chinook that incubate during the summer months. Temperatures in the winter-run spawning reach below Keswick Dam are largely controlled by the cold water pool in Shasta Reservoir and the Shasta temperature control device constructed in the 1990’s to manage cold water pool releases for the benefit of salmon. Currently, however, summer time flows are unnaturally high. Substantially reducing summer time flows, may result in elevated temperatures to the extent that it substantially increases travel time for cool water releases to reach the downstream end of the spawning reach, resulting in more time for the water to warm. However, stream temperatures will be controlled by a combination of cold water pool management in the reservoir j(reservoir level) and releases from that cold water pool (instream flows).

It is unclear how much, and at what point reduced flows in summer will increase temperature and how much that will negatively impact winter run. If substantially reducing flows creates negative impacts the endangered winter run irregardless of cold water pool management, then managers will be forced to maintain artificially high summer flows during winter run at incubation at the expense of increasing flows during other parts of the year for other species and other life-stages.

4.2.9 Juvenile Development and Rearing

Growth and rearing of juveniles is crucial to ensure that they grow fast enough to smolt before the onset of high temperature stresses common in the late spring. Smolts are typically >70-80mm and are able to survive in saltwater. Larger juveniles have a better chance of succeeding and surviving to the smoltification phase. “The rate of downstream migration of Chinook fingerlings appears to be both time and size dependent and may also be related to river discharge and the location of the Chinook in the river…Larger Chinook traveled downstream faster, and the rate of migration increased with the season” (Healey 1991). Growth is also important for avoiding other sources of stress and mortality such as lack of food, entrainment, predation, and disease. Larger fish are better able to compete for larger prey and avoid entrainment and predation. Larger juveniles have a competitive advantage over smaller fish in selecting prime positions in rearing areas (Fausch 1984 in Myrick and Cech), which can increase feeding rates (Alanara and Brannas 1997 in Myrick and Cech 2001). Larger fish also have more energy stores to withstand stresses imposed by disease.

There is great uncertainty about the suitability of the Delta for juvenile rearing and growth relative to rearing conditions farther upstream in the spawning reaches. The CALFED Strategic Plan for Ecosystem Restoration identified this question as one of the major uncertainties constraining the restoration planning process in the Bay-Delta watershed. Although Chinook salmon use other estuaries for rearing, most research and previous management actions on salmon in the Delta assume that juveniles suffer very high mortality in the Delta and has thus focused on moving smolt through the Delta as quickly as possible. Moyle (2002) found that “juveniles from other runs apparently do not spend as much time in the estuary, but pass through fairly rapidly on their way to sea. Whether or not this rapid passage is a recent phenomenon as the result of drastic changes in estuarine habitat or is the historical pattern is not clear”.

Fry appear to develop and grow in the tributaries, on inundated floodplains and in the Delta at different times until they become smolts and are large enough to migrate to the Ocean. There is strong evidence that juveniles rearing on inundated floodplains in the Yolo Bypass, a lowland transition zone between the spawning reaches and the Delta, had significantly higher growth rates than juveniles reared in the mainstem of the Sacramento River (Sommer et al. 2001). Sommer et al. (in preparation) attributed the higher growth rates to the increased area of suitable habitat, increased temperatures and increased food resources. Sommer et al. (2001) found that drift insects (primarily chironomids) were an order of magnitude more abundant in the Yolo

Bypass than the adjacent Sacramento River channel during 1998 and 1999 flood events. Seasonally inundated floodplains are also relatively free of exotic predators. "In the Central Valley during high flow periods, these fish historically moved into the floodplain, where they could rear for several months." (Moyle, 2002). Today, however, most of the rivers in the Sacramento Basin have been cut off from their floodplains, decreasing the available habitat for juveniles to develop and grow.

Less is known about the value of inundated floodplains relative to the gravel bedded reaches of the tributaries, which produce abundant food resources from macro-invertebrate production. Numerous studies indicate that gravel bedded reaches are more productive than sand and clay bottomed reaches that characterize the lower Sacramento. The increased food resources in the gravel bedded spawning reaches may be somewhat offset by the constant cold water, hypolimnetic releases from the dams, which may dampen growth. Channel incision, degraded riparian vegetation and degraded streambed complexity have been found to reduce the supply of organic detritus that invertebrates depend on for food, which may limit growth and survival of juvenile salmon that depend on invertebrates (Allan 1995 in CMARP). Incised channels in the Sacramento basin have cut off the rivers from their floodplains, which further limit access to food supplies (CMARP). These incised channels combined with high flows can result in fry and juveniles being washed down stream into less productive lowland reaches with high predator populations. Despite lower macroinvertebrate production, warmer water temperatures in the low-lying rivers and in the Delta may result in higher growth rates similar to observations from the Yolo bypass. Healey (1991) found that fry grow more rapidly in the Sacramento-San Joaquin estuary than in the rivers. However, others report that "fry that rear in the upper rivers experience a higher survival to smolting than fry that rear in the delta" (Kjelson et al. 1982, Brown 1986 in Healey, 1991).

Temperature has a major impact on growth. High water temperatures were found to stimulate smoltification and growth (Kreeger and McNeil 1992 in CMARP and SP Cramer, 2000 and Castleberry et al., 1991 in Myrick and Cech, 2001). Myrick and Cech (2001) conducted an extensive review of temperature effects on growth of juvenile Chinook in the Central Valley (Table 3.6). Although they found conflicting results, generally temperatures in the 60-66°F (15-19°C) range lead to high juvenile growth rates. When juveniles are rearing in February and March, temperatures in the tributaries are relatively low, cooler than temperatures needed for optimal growth. SP Cramer (2000) found that "higher water years result in cooler river temperatures [in the spring], which in turn can slow growth rates…However, Cramer et al. (1985) concluded from a variety of growth measurements that warmer temperatures, rather than lower flows, were driving growth of juvenile Chinook" (SP Cramer 2000). Higher growth rates may be a factor of slightly higher temperatures on the floodplains and in the Delta during this early spring period.

Table 3. Effects of temperature on growth of Juvenile Chinook in the Central Valley (Myrick and Cech, 2001 and Moyle, 2002)

Source	**Location**	**Maximum Growth**
Moyle (2002 referencing Marine)		55-64°F (13-18°C)
Rich (1987)	Nimbus State Fish Hatchery on American River	56-60°F (13-15°C)
Marine (1997)	Coleman National Fish Hatchery on Sacramento River	63-68°F (17-20°C)
Cech and Myrick (1999)	Nimbus State Fish Hatchery on American River	66°F (19°C)

Water temperatures greater than 77°F (25°C) were found to be lethal to juveniles in the Central Valley when exposed to these high temperatures for a long period of time, but they could withstand brief periods of high temperatures up to 84.2°F (29°C) (Myrick and Cech, 2001).

Although the mid water trawl surveys at Chipps Island measure smolt outmigration from the Delta (Baker et al. 1995), there are no measurements that identify where these outmigrating fish reared. Without this information it is impossible to estimate the relative importance to the population of fry reared in the Delta and on lower river floodplains compared with fry that rear in the tributaries before outmigrating. It is fairly clear, however, that the majority of juveniles migrate to the lower river and Delta soon after emergence. Therefore, we hypothesize that improving rearing conditions in the lower river and the Delta should increase overall escapement. Present management seems to focus on the quality of rearing habitat in the tributaries, but if the majority of young are moving out of the tributaries, it seems prudent to improve conditions for them as well. In order to understand where to focus limited resources where they will have the most impact on successful rearing, we need better information on the relative success of fish rearing in the lower river and Delta relative to fish rearing in the gravel bedded reaches of the tributaries.

Entrainment in water diversion facilities and predation, particularly from non-native bass, are also a major problem for salmon during the juvenile life stage. “Predators are commonly implicated as the principal agent of mortality among fry and fingerlings of chinook…[and] other fish are generally considered to be the most important predators of juvenile salmon” (Healey, 1991). Entrainment and predation are less related to flow then morality associated with high temperatures during the outmigration period. Juvenile growth rates probably affects mortality from predation and entrainment because smaller juveniles are more susceptible to mortality. Juvenile growth rates may also affect ultimate survival because faster growing juveniles and smolts migrate out of the system earlier in the spring before temperature becomes a major source of mortality and because larger juveniles travel downstream faster (Healey 1991, CMARP).

Contaminated agricultural and urban runoff may also increase outmigrating juvenile salmon’s susceptibility to disease, such as *Ceratomyxa*, which causes a high mortality rate in Chinook and flourishes in organic sediments and possibly in mine pits (CMARP p 19 and 20).

We hypothesize that improving juvenile growth rates will improve the rates of successful smolt outmgration and may also reduce mortality from diversions and predation. Based on robust results from research in the Yolo Bypass, it appears providing seasonally inundated floodplain habitat is perhaps the best way to ensure adequate growth before outmigration to the Delta and Ocean. If nothing else, providing seasonally inundated floodplain habitat will provide better habitat for the young that migrate or are washed out of the gravel bedded reaches early.

Increased flows during the rearing period combined with floodplain restoration should help increase overall growth rates and potentially decrease predation. Increased flows during this period should also dilute poor water quality. Increased flow may also decrease negative effects on salmon from contaminants and disease. Agricultural return flow from the west side of the San Joaquin did not cause any detrimental effects on growth and survival of hatchery-born Chinook salmon when the return flows were diluted by 50% or more with water from the San Joaquin (Saiki et al., 1992, from CMARP p 19).

Fall-Run

Fall-run Chinook usually emerge from the gravel as fry between January and March. Large portions of fry are immediately dispersed downstream to the lower rivers and the Delta, while some fry remain in the tributaries to rear (Kjelson et al. 1982 in Healey 1991, Moyle, 2002, and SP Cramer, 2000). SP Cramer (2000) found that peak migration of fry on the Stanislaus was associated with an increase in daily average flows. Different studies have found that fry and smolts are more abundant in the Sacramento-San Joaquin Delta at different times, depending on how long they remain in the upstream tributaries, before migrating to the ocean. “Most rearing occurs in freshwater habitats in the upper delta area, and the fry do not move into brackish water until they smoltify” (Kjelson et al., 1981, 1982 in Healey, 1991).

Higher flows during January through March d are more likely to result in inundated flood-plain or channel margin habitat ideal for rearing.

Late Fall-Run

Due to their late emergence in April and May, late-fall run are not able to migrate downstream before summer temperatures in the lower river become lethal. Rather most escapement probably results from juveniles that rear and over summer in the upper river. Increasing late spring and early summer may improve conditions for those fish that attempt to migrate out in the late spring and early summer as juveniles. Very large flows, however, would be necessary to create suitable temperature conditions in the lower river.

Winter-Run

Winter-run fry emerge from the spawning gravels from mid-June through mid-October (NMFS 1997). Because winter-run salmon spawning is concentrated upstream in the reaches below Keswick Dam, the entire Sacramento River serves as a nursery area for juvenile winter-run Chinook as they migrate downstream. Downstream movement of juveniles typically begins in August soon after fry emerge from redds. Rotary screw traps at RBDD usually record peaks in the abundance of winter-run salmon fry in September and October. However, following these initial pulses of fry, winter-run juveniles steadily stream past RBDD through March (Kimmerer and Brown, in prep.). Most juvenile winter-run Chinook reach the Delta between January and April, when they pose a conflict with Delta pumping operations designed to increase South of Delta storage during winter months when conflicts with protections for Delta smelt are reduced.

Higher flows during the out migration period for winter run are likely to result in inundated flood-plain or channel margin habitat ideal for rearing. More food will reduce mortality to the extent food is limiting and faster growing fish will have higher survival against gape limited predators or through the smoltification process.

Spring-Run

The rearing and outmigration patterns exhibited by spring-run Chinook salmon are highly variable, with fish rearing anywhere from 3 to 15 months before outmigrating to the ocean (Fisher 1994). Variation in length of juvenile residence may be observed both within and among streams (e.g., Butte versus Mill creeks, USFWS 1995, as cited in Yoshiyama et al. 1998). Some may disperse downstream soon after emergence as fry in March and April, with others smolting after several months of rearing, and still others remaining to oversummer and emigrate as yearlings (USFWS 1995, as cited in Yoshiyama et al. 1998). Scale analysis indicates that most returning adults have emigrated as subyearlings (Myers et al. 1998). Calkins et al. (1940, as cited in Myers et al. 1998) conducted an analysis of scales of returning adults and estimated that greater than 90% had emigrated as subyearlings, at about 3.5 in (88 mm).

Spring-run that migrate early in their first year could benefit substantially from inundated floodplain habitat and channel margins that higher flows could provide. The excerpt below drafted by Stillwater (2003) clearly explains the phenomena:

> "As stream-type salmon, a fraction of spring-run juveniles may spend a summer rearing in natal streams before emigrating to the ocean. After emergence, spring-run juveniles display agonistic behavior, establishing and defending territories. This behavior means that summer rearing habitat can be quickly saturated, even if escapements are low, because of the area required to support each juvenile. Spring-run that migrate downstream as fry often represent those individuals displaced as a result of rearing habitat saturation in upstream reaches. Because these fry are forced to migrate downstream at a small size < 1.6 m (40 mm), they are vulnerable to predation, such that the fry component may not contribute significantly to future escapements. However, recent research conducted on the Butte Creek population of spring-run salmon suggest that successful rearing by spring-run fry in the Sutter Bypass may be stimulating the recent increase in escapements. Generally, the Deer and Mill creek populations spring-run do not seem to have the same success in fry rearing. To improve fry rearing potential for the Deer and Mill Creek populations, we recommend the creation of a dedicated floodplain/bypass area along the mainstem Sacramento River downstream of Deer and Mill creeks. A bypass in the vicinity of Deer and Mill creeks would provide rearing habitat to fry and juveniles outmigrating to the main stem from these important spawning tributaries for remaining wild-type spring-run Chinook. Such a bypass should be constructed to provide high-quality rearing habitat at relatively low flows, so that the habitat is available for a large portion of every winter, even during drier years.

4.2.10 Smolt Outmigration

As mentioned in the previous section, after fry emerge from the gravel the majority disperse downstream, especially during increases in flows or after storm events. Whether young fish migrate out of the tributaries soon after emergence or whether they rear in the tributaries, they eventually undergo smoltification and make their physiological transition to salt water. Several factors trigger smoltification, including changing hormone concentrations, increasing photoperiod, increasing temperature, and increasing body size (Myrick and Cech, 2001). While most of these factors cannot be influenced by changing management actions in the tributaries or the Delta and are not discussed in this report, temperature and body size are affected by flow and can be influenced by reservoir reoperation.

Smolts require lower temperatures than rearing juveniles. While higher temperatures in the 60-66°F (15-19°C) range can optimize growth of juveniles and better prepare them for smoltification earlier, lower temperatures are more optimal during the smoltification process. A comprehensive study by Myrick and Cech (2001) found that Chinook have a better chance of surviving in the Ocean if they undergo smoltification at lower temperatures, ranging from 50-63.5°F (10-17.5 °C). Warmer temperatures in the February –March period (which occur on floodplains) stimulate growth of juveniles so they are larger before they undergo smolification and therefore larger when they enter the Ocean (Myrick and Cech, 2001). Larger juveniles are also able to smolify before harmful high late spring temperatures set in. Cooler temperatures are necessary in the smolt outmigration period of April – June. The need for warmer temperatures in the early spring and cooler temperatures in late spring reflects the historical hydrograph, where large, cold snowmelt flows dominated the Sacramento Basin later in the spring.

Body size is an important function of the success of outmigrating smolts and the development to smoltification (Dlarke and Shelbourn 1985; Johnssson and Clarke 1988 in Myrick and Cech, 2001). It is important that Chinook reach an appropriate size for smolting before they arrive in saltwater. Relatively warm temperatures can be beneficial for growth provided adequate food supply. Increases inundated floodplain habitat provides the type of habitat that allow juveniles to grow larger before smoltification (Sommer et al, 1991).

High water temperatures, low flows and entrainment may cause increased mortality rates in outmigrating smolts and affect growth of juvenile Chinook. High water temperatures, particularly in May and June may pose the largest threat to juveniles that remain in the tributaries and in the Delta later in the spring. Baker et al (1995) found that 50% of Chinook smolt that migrate through the Delta die when temperatures reach 72-75°F (22-24°C) McCullough (1999 in Moyle) found that few fish can survive temperatures greater than 75.2°F (24°C) even for short periods of time.

Prolonged periods of high flows from January through June, especially from late February through mid-April, will reduce temperatures and help flush out outmigrating juveniles and smolt (CMARP). There are several programs underway and several measures that could be taken to improve juvenile outmigration and survival. Increased flows during outmigration improve juvenile/smolt survival in the Sacramento basin tributaries and Delta. Studies have shown that survival of fry and smolts passing through the Sacramento-San Joaquin River delta were highly correlated with discharge of the Sacramento River (Healey, 1991 and USFWS, 1998 in SP Cramer). Studies from the Stanislaus River shows that Smolt survival was high (about 78%) when releases from were increased in late April in 1986 and 1988, but were low (28%) when releases were lower in April 1989. A substantial increase in migrating juvenile was measured when flows were increased in the Stanislaus River for seven days in April 1995 (SP Cramer 1995 in CMARP).

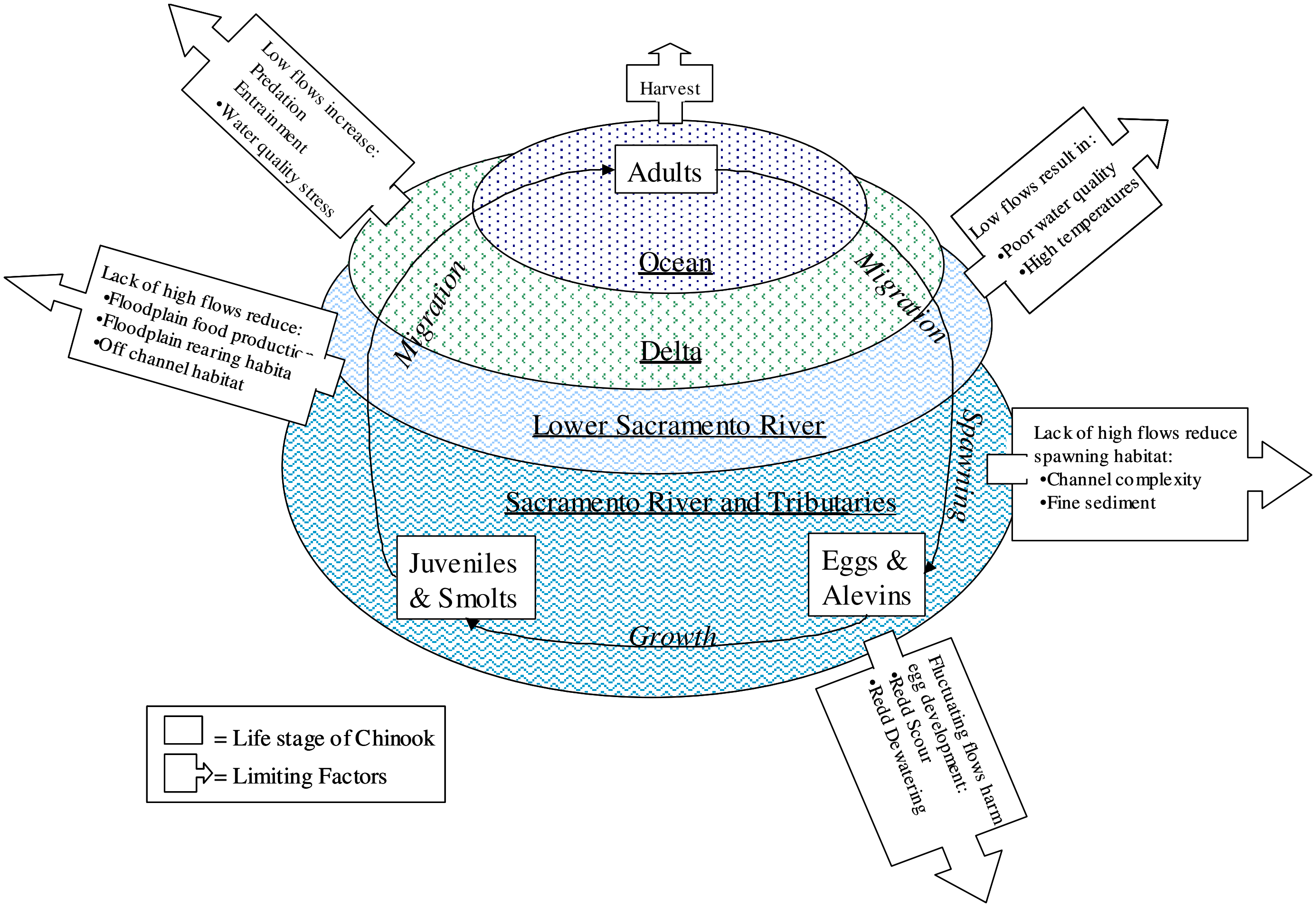


Figure 4: This conceptual model for Chinook salmon illustrates the life cycle of the Chinook in the Sacramento River, factors that increase Chinook mortality during their life cycle, and how restoration can improve the conditions of these fish.

Appendix E
Estimates of Project Costs Technical Memorandum

DAVIDS
ENGINEERING, INC

Specialists in Ag Water Management

Technical Memorandum

TO: File

FROM: Davids Engineering, Inc.

DATE: October 4, 2011

SUBJECT: Estimation of Sacramento Valley Conjunctive Water Management Program Costs

Background and Objectives

The objective of this effort was to estimate implementation costs for Sacramento Valley Conjunctive Water Management Program. The cost estimates were developed based on an evaluation of capital, operations, maintenance, and mitigation costs associated with program. All costs were estimated in 2010 dollars.

The following pumping scenarios were evaluated:

- 300 TAF Summer Pumping, New Well Field
- 300 TAF Summer Pumping, Existing Well Field
- 150 TAF Summer Pumping, New Well Field
- 150 TAF Summer Pumping, Existing Well Field
- 150 TAF Fall Pumping, New Well Field
- 150 TAF Fall Pumping, Existing Well Field
- 150 TAF Summer and Fall Pumping, New Well Field
- 150 TAF Summer and Fall Pumping, Existing Well Field

This brief technical memorandum describes the estimation of implementation costs.

Summary of Program Implementation Cost Items

Capital, operations and maintenance, and mitigation cost items associated with the Program are summarized in Table 1. For each cost item, the nature of the cost is described, along with the basis upon which the associated cost was estimated.

Global Cost Parameters

The following cost parameters were assumed for the cost estimates:

- Contingency applied to all cost items: 20%
- Engineering and project management as a percentage of up-front capital costs: 12%
- Percent of normal maintenance required for Program wells in non-pumping years: 20%
    - Assumes that maintenance requirements are less in years the Program wells are not operated.
- PG&E energy rate paid for project pumping: $0.22/kWh

Table 1. Capital, O&M, and Mitigation Cost Items Associated with Sacramento Valley Conjunctive Water Management Program.

Cost Category	Cost Item	Item Description	Basis/Comment
Capital	Construct and equip shallow irrigation well	Construct new, typical ~450 foot deep irrigation production well in regional aquifer. Purchase land, electrical line extension, install well pad, pump, electrical motor and controls, discharge piping and connection to open canal, security enclosure.	Well driller interview/discussion to estimate unit costs. Estimate quantities based on available well surveys and project pumping requirements.
Capital	Construct and equip deep irrigation well	Construct new, typical ~1,400 foot deep irrigation production well in deep aquifer. Purchase land, electrical line extension, install well pad, pump, electrical motor and controls, discharge piping and connection to open canal, security enclosure.	Recent SCF bids to estimate unit costs. Estimate quantities based on available well surveys and project pumping requirements.
Capital	Rehabilitate existing shallow irrigation well (inspect and reinstall)	Remove existing pump and motor; perform downhole video and qualification assessment; reinstall existing pump and motor; discharge piping and connection to open canal, security enclosure. In some cases, well may require rehabilitation (acid wash) and/or upgrade of electrical. Also, conversion from Diesel to electric and electrical line extension may be required.	Well driller interview/discussion to estimate unit costs. Estimate quantities based on available well surveys and project pumping requirements.
Capital	Rehabilitate existing shallow irrigation well (inspect and rebuild)	Remove existing pump and motor; perform downhole video and qualification assessment; rebuild existing pump and motor, upgrade electric controls; discharge piping and connection to open canal, security enclosure. In some cases, well may require rehabilitation (acid wash) and/or upgrade of electrical. Also, conversion from Diesel to electric and electrical line extension may be required.	Well driller interview/discussion to estimate unit costs. Estimate quantities based on available well surveys and project pumping requirements.
Capital	Rehabilitate existing shallow irrigation well (inspect and replace)	Remove existing pump and motor; perform downhole video and qualification assessment; replace existing pump and motor; discharge piping and connection to open canal, security enclosure. In some cases, well may require rehabilitation (acid wash) and/or upgrade of electrical. Also, conversion from Diesel to electric and electrical line extension may be required.	Well driller interview/discussion to estimate unit costs. Estimate quantities based on available well surveys and project pumping requirements.
Capital	Purchase and install SCADA equipment at production or monitoring well site	Furnish and install RTU, sensors, enclosure, radio, antenna, complete, installed.	Estimate unit costs based on data from ITRC. Estimate quantities based on number of project and monitoring wells required.
Capital	Construct dedicated monitoring well	Contruct new, typical 1,200-foot triple completion, dedicated monitoring well	Estimate unit costs based on input from DWR and well driller. Estimate quantites based on required number of project wells.
O&M	Electrical energy costs for project pumping	PG&E energy costs associated with project pumping.	Estimate unit costs based on PG&E rates, estimated lift from GW model and typical flow rates, OPPE from CIT APEP. Estimate quantities from SW model.

Table 1 (Continued). Capital, O&M, and Mitigation Cost Items Associated with Sacramento Valley Conjunctive Water Management Program.

Cost Category	Cost Item	Item Description	Basis/Comment
O&M	Water level monitoring, feedback and realtime management	During and following years of project pumping, conduct water level monitoring, operate and maintain GW model, manage pumping in real time to minimize or avoid impacts, confer with appropriate authorities, prepare periodic reports of project operations.	Estimate staffing requirements and costs for individual tasks during pumping and non-pumping years based on professional judgement.
O&M	Project operations	Operations forecasting and scheduling according to program objectives and operating rules.	Estimate staffing requirements and costs for individual tasks during pumping and non-pumping years based on professional judgement.
Mitigation	Construct domestic well	Replacement of domestic wells with yield impacted by project pumping.	Estimate unit costs based on well driller information. Estimate quantities based on analysis of yield impacted wells using GW model results from 1987 to 2003.
Mitigation	Payments for incremental agricultural pumping costs	Reimbursement for energy costs associated with increased lift caused by interference drawdown from the project.	Estimate unit costs based on PG&E rates, estimated lift from GW model and typical flow rates, OPPE from CIT APEP. Estimate quantities from GW/SW model.
Mitigation	Payments for incremental domestic pumping costs	Reimbursement for energy costs associated with increased lift caused by interference drawdown from the project.	Estimate unit costs based on PG&E rates, estimated lift from GW model and typical flow rates, OPPE from CIT APEP. Estimate quantities from spatially distributed Census data and USGS per capita water use rates.
Mitigation	Administration, outreach, complaint response and dispute resolution, mitigation operations, and legal counsel.	Provide administration of monitoring and mitigation, conduct public outreach regarding observed impacts, handle impacts complaints/disputes. Provide legal support.	Estimate staffing requirements and costs for individual tasks during pumping and non-pumping years based on professional judgement.

Domestic Well Replacement Quantities and Costs

Domestic Well Replacement Quantities

The number of domestic wells requiring replacement was estimated for each pumping scenario based on the analysis of peak drawdown relative to screened interval length for domestic wells in the project area with available screen length data, described elsewhere. The number of wells impacted was scaled up based on the total number of domestic, industrial, public, stock, and other potentially wells in the study area, as reported by DWR. The estimated number of wells requiring replacement is summarized in the table below.

Pumping Scenario	Well Field	Impacted Wells[1] Min	Max	Average
300K Summer	New	63	172	118
	Existing	167	310	238
150K Summer	New	7	29	18
	Existing	99	189	144
150K Fall	New	7	32	19
	Existing	92	196	144
150K Summer and Fall	New	9	27	18
	Existing	69	142	105

1. Estimates of probable range of impacts based on analysis of peak interference drawdown relative to screened interval length for domestic wells in the project area with available screen length data. The number of wells impacted was scaled up based on the total number of domestic, industrial, public, stock, and other potentially impacted wells within the study area.

Unit Cost for Domestic Well Replacement

The unit cost of replacement for domestic wells was estimated to be $18,200, as summarized below. Based on an amortization rate of 3%, the annualized cost per well replaced was estimated to be $1,580.

Cost Item	Capital	Life (yr)	Amort. Rate	Annual Capital
Construction of New Domestic Well	$10,000	30	3%	$ 510
Installation of pump/motor/tank	$2,500	10	3%	$ 293
Abandon Old Domestic Well	$1,500	30	3%	$ 77
SUBTOTAL	$14,000			$880
Engineering and Project Management	$1,400		(10%)	$140
Contingencies	$2,800		(20%)	$560
TOTALS	$18,200			$1,580

NOTE: It is assumed that domestic wells replaced by the program will be maintained at the expense of the well owner.

Total Cost of Domestic Well Replacement

Combining the estimated quantity of domestic wells requiring replacement with the estimated unit cost of well replacement, the total cost of domestic well replacement was calculated and is summarized below.

		Total Capital			Annual Capital		
Pumping Scenario	Well Field	Min	Max	Average	Min	Max	Average
300K Summer	New	$1,151,660	$3,137,280	$2,144,470	$99,966	$272,322	$186,144
	Existing	$3,037,999	$5,639,161	$4,338,580	$263,705	$489,491	$376,598
150K Summer	New	$119,137	$536,117	$327,627	$10,341	$46,536	$28,439
	Existing	$1,806,914	$3,435,123	$2,621,018	$156,844	$298,176	$227,510
150K Fall	New	$119,137	$575,830	$347,484	$10,341	$49,983	$30,162
	Existing	$1,667,921	$3,574,116	$2,621,018	$144,779	$310,241	$227,510
150K Summer and Fall	New	$158,850	$496,405	$327,627	$13,788	$43,089	$28,439
	Existing	$1,250,941	$2,581,306	$1,916,123	$108,584	$224,063	$166,323

Project Well Construction and Rehabilitation Costs

Quantity of Project Wells Required

The number of project wells required was estimated based on estimates of the number and distribution of existing production wells in the study area, typical production well capacities in the study area, peak monthly pumping volumes for each pumping scenario, and assumptions regarding downtime for project wells. Estimated well capacities are summarized below.

Average Flow Rate per Well (gpm)[1]

	GCID	WCWD	Richvale
Existing Wells	2800	2400	2400
New Shallow Wells[2]	2800	2400	2400
New Deep Wells[2]	2800	2400	2400

1. GCID and WCWD average flow rates estimated based on average values from well surveys in each district. Richvale ID flow rate assumed to be similar to WCWD.
2. New wells assumed to have flow rates similar to existing wells.

Maximum monthly pumping volumes by scenario, estimated based on the reservoir operations model, are summarized below.

Maximum Monthly Pumping Volume (ac-ft)

Pumping Scenario	GCID	WCWD[3]	Richvale[3]
300K Summer	50,000	12,500	12,500
150K Summer	25,000	6,250	6,250
150K Fall	40,000	10,000	10,000
150K Summer and Fall	15,000	3,750	3,750

3. Equal pumping volumes assumed for WCWD and Richvale ID

The quantities of simultaneously operated project wells required to meet peak pumping requirements for each pumping scenario are summarized below.

Number of Simultaneously Operated Wells Required to Satisfy Project Pumping Requirements[4]

Pumping Scenario	Well Field	GCID	WCWD	Richvale
300K Summer	New	133	39	39
	Existing	133	39	39
150K Summer	New	66	19	19
	Existing	66	19	19
150K Fall	New	106	31	31
	Existing	106	31	31
150K Summer and Fall	New	40	12	12
	Existing	40	12	12

4. Assume pumps will operate every day, 24 hours per day at peak.

Due to periodic maintenance and other unknowns, it is likely that some project wells will be inoperable at times. As a result, the number of additional project wells required to ensure sufficient pumping capacity during peak production was estimated as described below.

Additional Wells Required to Allow for Downtime

Contingency for maintenance/repair of existing wells during peak pumping: 5%
Contingency for strategic shutdown of project wells to avoid yield impacts to domestic wells: 10%
TOTAL CONTINGENCY: 15%

Total Number of Project Wells Required to Satisfy Project Pumping Requirements

Pumping Scenario	Well Field	GCID	WCWD	Richvale
300K Summer	New	153	45	45
	Existing	153	45	45
150K Summer	New	76	22	22
	Existing	76	22	22
150K Fall	New	122	36	36
	Existing	122	36	36
150K Summer and Fall	New	46	13	13
	Existing	46	13	13

Quantity of Additional Production Wells Needed for Existing Well Field Scenarios

Even under the existing well field scenarios, additional production wells are needed to meet peak pumping demands in some areas.

Only a portion of existing wells are likely to enter the program due to lack of grower willingness, well condition, or other issues. As a result, the number of existing wells entering the program will be less than the total number of existing wells.

The estimated number of existing production wells in each area, the number of existing wells expected to enter the program, and the corresponding number of additional production wells required for the existing well field scenarios are summarized on the following page.

Existing Wells Potentially Available to Support Project Pumping

	GCID[5]	WCWD[6]	Richvale[7]
Existing Irrigation Wells	155	131	77

5. Estimated as number of wells listed in GCID well survey.
6. Estimated as number of wells listed in WCWD well survey, multiplied by 50%. It appears some wells listed may be domestic or abandoned.
7. Estimated based on number of wells in WCWD assuming equal number of wells per section.

Existing Wells Ultimately Included in Program

Existing wells not suitable for project due to nonideal location, owner unwillingness, or well unsuitable:	67%

	Existing Wells Entering Program		
Pumping Scenario	GCID	WCWD	Richvale
300K Summer	51	43	25
150K Summer	51	22	22
150K Fall	51	36	25
150K Summer and Fall	46	13	13

Additional New Shallow Irrigation Wells Needed for Existing Well Field Pumping Scenarios

Pumping Scenario	GCID	WCWD	Richvale
300K Summer	102	2	20
150K Summer	25	-	-
150K Fall	71	-	11
150K Summer and Fall	-	-	-

Existing Well Rehabilitation Quantities

Existing wells entering the Program will need inspection and in many cases rehabilitation. Estimates of the quantity of wells entering the program requiring rehabilitation are summarized below for each of the existing well field pumping scenarios.

Number of Existing Wells Requiring Upgrades or Repairs

Proportion of existing wells requiring down hole inspection:	100%	
Proportion of existing wells requiring rehabilitation:	30%	
Proportion of existing wells requiring well seal:	20%	(based on GCID well survey number of wells with no seal)
Proportion of existing wells requiring reinstallation of existing pump and motor:	50%	
Proportion of existing wells requiring rebuild of existing pump and motor:	30%	
Proportion of existing wells requiring replacement of pump and motor:	20%	
Proportion of existing wells requiring Diesel --> Electric conversion:	80%	

	Downhole Inspection			Well Rehabilitation			Construct Well Seal		
Pumping Scenario	GCID	WCWD	Richvale	GCID	WCWD	Richvale	GCID	WCWD	Richvale
300K Summer	51	43	25	15	13	8	10	9	5
150K Summer	51	22	22	15	7	7	10	4	4
150K Fall	51	36	25	15	11	8	10	7	5
150K Summer and Fall	46	13	13	14	4	4	9	3	3

	Reinstall Pump and Motor			Rebuild Pump and Motor			Replace Pump and Motor		
Pumping Scenario	GCID	WCWD	Richvale	GCID	WCWD	Richvale	GCID	WCWD	Richvale
300K Summer	26	22	13	15	13	8	10	9	5
150K Summer	26	11	11	15	7	7	10	4	4
150K Fall	26	18	13	15	11	8	10	7	5
150K Summer and Fall	23	7	7	14	4	4	9	3	3

	Diesel --> Electric Conversion		
Pumping Scenario	GCID	WCWD	Richvale
300K Summer	81	1	16
150K Summer	20	-	-
150K Fall	57	-	8
150K Summer and Fall	-	-	-

Unit Costs for Well Construction, Rehabilitation, Operation, and Maintenance

Unit costs for well construction and rehabilitation were estimated based on discussion with well drillers and based on recent well costs for test wells.

The estimated unit cost for construction, operation, and maintenance of a new deep project well is summarized on Page 9.

The estimated unit cost for construction, operation, and maintenance of a new shallow project well is summarized on Page 10.

The estimated cost for purchase, operation, and maintenance of an existing production well is summarized on Page 11.

It is anticipated that existing Diesel wells would be converted to electrical power upon entering the program. The estimated cost for conversion of existing Diesel wells to electrical drive is summarized on Page 12.

Estimated unit costs for well rehabilitation are summarized on Page 13.

It is anticipated that project wells will be equipped with SCADA to support monitoring of well operation, water level, and pumped volume. Estimated unit costs for SCADA are summarized on Page 14.

stimated Cost to Construct, Maintain, and Operate New Irrigation Well (Lower Aquifer)

eneral Characteristics

Depth:	1200 ft	Estimated Specific Capacity:	50 gpm/ft	Total Dynamic Head:	138 ft
Diameter:	16 in	Estimated OPPE:	65%	Water Horsepower:	87 HP
Discharge:	2500 gpm	Estimated Static Water Level:	80 ft	Input Horsepower:	134 HP
		Estimated Friction Losses and Discharge Head:	8 ft		

onstruction and Maintenance Cost

Discount Rate: 3%

Item	Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.	
Well drilling, testing, and completion	$ 250 per ft	1200	$ 300,000	60	$ 10,840	1%	$ 3,000	
Construct pad, install pump, electrical motor and controls, discharge piping	$ 100,000 ea	1	$ 100,000	30	$ 5,102	3%	$ 3,000	
Connection to distribution system (18" buried PVC)	$ 80 per ft	350	$ 28,000	50	$ 1,088	1%	$ 280	
Land purchase	$ 40,000 per ac	0.25	$ 10,000	100	$ 316		$ -	
Electrical service, 3-phase	$ 105,600 per mi	0.25	$ 26,400	50	$ 1,026		$ -	
Transformer and Power Drop	$ 12,500 ea	1	$ 12,500	30	$ 638		$ -	
Vandalism enclosure	$ 3,800 ea	0	$ -	20	$ -		$ -	(included in scada cost)
SUBTOTALS			$ 476,900		$ 19,010		$ 6,280	
Engineering and Project Management (12%)			$ 57,228		$ 2,281			
Contingencies (20%)			$ 95,380		$ 3,802		$ 1,256	
TOTALS			$ 629,508		$ 25,094		$ 7,536	

perations Cost

Total Dynamic Head:	138	kwh per ac-ft:	217	Pumping energy cost:	$48 per ac-ft
OPPE:	65%	Electrical rate:	$0.22 per kwh		

Estimated Cost to Construct, Maintain, and Operate New Irrigation Well (Regional Aquifer)

General Characteristics

Depth:	450 ft	Estimated Specific Capacity:	30	gpm/ft	Total Dynamic Head:	171	ft
Diameter:	16 in	Estimated OPPE:	65%		Water Horsepower:	108	HP
Discharge:	2500 gpm	Estimated Static Water Level:	80	ft	Input Horsepower:	166	HP
		Estimated Friction Losses and Discharge Head:	8	ft			

Construction and Maintenance Cost

Discount Rate: 3%

Item	Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.	
Well drilling, testing, and completion	$ 250 per ft	450	$ 112,500	60	$ 4,065	1%	$ 1,125	
Construct pad, install pump, electrical motor and controls, discharge piping	$ 100,000 ea	1	$ 100,000	30	$ 5,102	3%	$ 3,000	
Connection to distribution system (18" buried PVC)	$ 80 per ft	350	$ 28,000	50	$ 1,088	1%	$ 280	
Land purchase	$ 40,000 per ac	0.25	$ 10,000	100	$ 316		$ -	
Electrical service, 3-phase	$ 105,600 per mi	0.25	$ 26,400	50	$ 1,026		$ -	
Transformer and Power Drop	$ 12,500 ea	1	$ 12,500	30	$ 638		$ -	
Vandalism enclosure	$ 3,800 ea	0	$ -	20	$ -		$ -	(included in SCADA cost)
SUBTOTALS			$ 289,400		$ 12,235		$ 4,405	
Engineering and Project Management (12%)			$ 34,728		$ 1,468			
Contingencies (20%)			$ 57,880		$ 2,447		$ 881	
TOTALS			$ 382,008		$ 16,151		$ 5,286	

Operations Cost

Total Dynamic Head:	171	kwh per ac-ft:	270	Pumping energy cost:	$59 per ac-ft
OPPE:	65%	Electrical rate:	$0.22 per kwh		

stimated Cost to Purchase, Maintain, and Operate Existing Irrigation well

eneral Characteristics

Depth: 450 ft
Diameter: 16 in
Discharge: 2500 gpm

Estimated Specific Capacity: 30 gpm/ft
Estimated OPPE: 65%
Estimated Static Water Level: 80 ft
Estimated Friction Losses and Discharge Head: 8 ft

Total Dynamic Head: 171 ft
Water Horsepower: 108 HP
Input Horsepower: 166 HP

onstruction and Maintenance Cost

Discount Rate: 3%

Item	Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.	
Well drilling, testing, and completion	$ 250 per ft	450	$ 112,500	60	$ 4,065	1%	$ 1,125	
Construct pad, install pump, electrical motor and controls, discharge piping	$ 100,000 ea	0.5	$ 50,000	30	$ 2,551	3%	$ 1,500	(motor, pad, panels not purchased with wel
Connection to distribution system (18" buried PVC)	$ 80 per ft	350	$ 28,000	50	$ 1,088	1%	$ 280	
Land purchase	$ 40,000 per ac	0.25	$ 10,000	100	$ 316		$ -	
Electrical service, 3-phase	$ 105,600 per mi	0	$ -	50	$ -		$ -	(not purchased with well)
Transformer and Power Drop	$ 12,500 ea	0	$ -	30	$ -		$ -	(not purchased with well)
Vandalism enclosure	$ 3,800 ea	0	$ -	20	$ -		$ -	(included in SCADA cost)
SUBTOTALS			$ 200,500		$ 8,021		$ 2,905	
Engineering and Project Management (12%)			$ 24,060		$ 962			
Contingencies (20%)			$ 40,100		$ 1,604		$ 581	
TOTALS			$ 264,660		$ 10,587		$ 3,486	

PURCHASE COST (ASSUME 1/2 COST OF NEW WELL DUE TO WEAR ON COMPONENTS) $ 132,330

perations Cost

Total Dynamic Head: 171
OPPE: 65%

kwh per ac-ft: 270
Electrical rate: $0.22 per kwh

Pumping energy cost: $59 per ac-ft

Estimated Cost to Convert Diesel to Electric Irrigation Well

General Characteristics

Depth:	450 ft	Estimated Specific Capacity:	30 gpm/ft	Total Dynamic Head:	171 ft
Diameter:	16 in	Estimated OPPE:	65%	Water Horsepower:	108 HP
Discharge:	2500 gpm	Estimated Static Water Level:	80 ft	Input Horsepower:	166 HP
		Estimated Friction Losses and Discharge Head:	8 ft		

Construction and Maintenance Cost

Discount Rate: 3%

Item	Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.	
Well drilling, testing, and completion	$ 250 per ft	0	$ -	60	$ -	1%	$ -	(included in purchase cost)
Construct pad, install pump, electrical motor and controls, discharge piping **(pad, motor, and controls only)**	$ 100,000 ea	0.5	$ 50,000	30	$ 2,551	3%	$ 1,500	(pad, motor, and controls only)
Connection to distribution system (18" buried PVC)	$ 80 per ft	0	$ -	50	$ -	1%	$ -	(included in purchase cost)
Land purchase	$ 40,000 per ac	0	$ -	100	$ -		$ -	(included in purchase cost)
Electrical service, 3-phase	$ 105,600 per mi	0.25	$ 26,400	50	$ 1,026		$ -	
Transformer and Power Drop	$ 12,500 ea	1	$ 12,500	30	$ 638		$ -	
Vandalism enclosure	$ 3,800 ea	0	$ -	20	$ -		$ -	(included in SCADA cost)
SUBTOTALS			$ 88,900		$ 4,215		$ 1,500	
Engineering and Project Management (12%)			$ 10,668		$ 506			
Contingencies (20%)			$ 17,780		$ 843		$ 300	
TOTALS			$ 117,348		$ 5,563		$ 1,800	

Operations Cost

Total Dynamic Head:	171	kwh per ac-ft:	270	Pumping energy cost:	$59 per ac-ft
OPPE:	65%	Electrical rate:	$0.22 per kwh		

Estimated Costs for Rehabilitation of Existing Wells

Discount Rate: 3%

Cost Item	Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.	
Downhole Inspection	$ 3,000 ea	1	$ 3,000	25	$ 120			(includes pump and motor removal)
Well Rehabilitation	$ 5,000 ea	1	$ 5,000	25	$ 200			(rehab screen, acid wash and brush)
Construct Well Seal	$ 5,000 ea	1	$ 5,000	25	$ 200			
Reinstall Pump and Motor	$ 3,000 ea	1	$ 3,000	25	$ 120			
Rebuild Pump and Motor	$ 15,000 ea	1	$ 15,000	25	$ 600			
Replace Pump and Motor	$ 60,000 ea	1	$ 60,000	25	$ 2,400			

These represent upfront costs of bringing existing wells into the program. Cost associated with ongoing well maintenance have been estimated separately for newly constructed wells and will also apply to rehabilitated wells once brought in to program.

Estimated Cost to Equip Production Well with SCADA

Construction and Maintenance Cost

Discount Rate: 3%

Item		Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.
RTU, monitoring only		$ 12,500 ea	1	$ 12,500	15	$ 1,047	10%	$ 1,250
Antenna, mast, and cable		$ 3,000 ea	1	$ 3,000	15	$ 251	10%	$ 300
Vandalism enclosure		$ 3,800 ea	1	$ 3,800	25	$ 218	2%	$ 76
Water level sensor		$ 2,000 ea	1	$ 2,000	15	$ 168	10%	$ 200
Panametrics flow meter		$ 8,100 ea	1	$ 8,100	15	$ 679	10%	$ 810
SUBTOTALS				$ 29,400		$ 2,363		$ 2,636
Engineering and Project Management	(12%)			$ 3,528		$ 284		
Contingencies	(20%)			$ 5,880		$ 473		$ 527
TOTALS				$ 38,808		$ 3,119		$ 3,163

In addition to production wells, it is anticipated that monitoring wells will be installed as part of the project to support monitoring of water level impacts and mitigation activities. The estimated unit cost for construction and maintenance of a triple-completion monitoring well is summarized on Page 16, along with the estimated unit cost to equip the well with SCADA and to maintain the SCADA system.

Estimated Cost to Construct and Maintain Dedicated Monitoring Well

General Characteristics

Max Depth:	1400 ft
Completions:	triple

Construction and Maintenance Cost

Discount Rate: 3%

Item		Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.
Triple completion monitoring well		$ 100,000 ea	1	$ 100,000	50	$ 3,887	1%	$ 1,000
SUBTOTALS				$ 100,000		$ 3,887		$ 1,000
Engineering and Project Management	(12%)			$ 12,000		$ 466		
Contingencies	(20%)			$ 20,000		$ 777		$ 200
TOTALS				$ 132,000		$ 5,130		$ 1,200

Estimated Cost to Equip Monitoring Well with SCADA

Construction and Maintenance Cost

Discount Rate: 3%

Item		Unit Cost	Qty	Total	Life (yr)	Annual	Maint. %	Ann. Maint.
RTU, monitoring only		$ 12,500 ea	1	$ 12,500	15	$ 1,047	10%	$ 1,250
Antenna, mast, and cable		$ 3,000 ea	1	$ 3,000	15	$ 251	10%	$ 300
Vandalism enclosure		$ 3,800 ea	1	$ 3,800	25	$ 218	2%	$ 76
Water level sensor		$ 2,000 ea	3	$ 6,000	15	$ 503	10%	$ 600
Panametrics flow meter		$ 8,100 ea	0	$ -	15	$ -	10%	$ -
SUBTOTALS				$ 25,300		$ 2,019		$ 2,226
Engineering and Project Management	(12%)			$ 3,036		$ 242		
Contingencies	(20%)			$ 5,060		$ 404		$ 445
TOTALS				$ 33,396		$ 2,665		$ 2,671

Total Costs for Well Construction, Rehabilitation, and Maintenance

Total capital costs for well construction or purchase for each pumping scenario are summarized below for each pumping scenario.

	300 TAF Summer Pumping, New Well Field					300 TAF Summer Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Construct and Equip Deep Irrigation Well	243	ea	$629,508	$152,970,444	$ 6,097,745	0	ea	$629,508	$ -	$ -
Construct and Equip Shallow Irrigation Well	0	ea	$382,008	$ -	$ -	123	ea	$382,008	$47,016,781	$ 1,987,795
Rehabilitate Existing Shallow Irrigation Well	0	ea[1]	$117,378	$ -	$ -	120	ea[1]	$117,378	$14,076,252	$ -
Purchase Existing Irrigation Well	0	ea	$132,330	$ -	$ -	120	ea	$132,330	$15,869,278	$ 1,269,641
Construct Triple-Completion Monitoring Well[2]	24	ea	$132,000	$ 3,207,600	$ 124,665	24	ea	$132,000	$ 3,207,600	$ 124,665
Equip Production and Monitoring Wells with SCADA	267	ea	$ 38,316	$ 10,241,867	$ 822,612	267	ea	$ 26,450	$ 7,069,978	$ 822,612
TOTALS				$166,419,911	$ 7,045,022				$87,239,889	$ 4,204,712

	150 TAF Summer Pumping, New Well Field					150 TAF Summer Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Construct and Equip Deep Irrigation Well	120	ea	$629,508	$ 75,540,960	$ 3,011,232	0	ea	$629,508	$ -	$ -
Construct and Equip Shallow Irrigation Well	0	ea	$382,008	$ -	$ -	25	ea	$382,008	$ 9,492,899	$ 401,345
Rehabilitate Existing Shallow Irrigation Well	0	ea[1]	$117,378	$ -	$ -	95	ea[1]	$117,378	$11,168,555	$ -
Purchase Existing Irrigation Well	0	ea	$132,330	$ -	$ -	95	ea	$132,330	$12,591,200	$ 1,007,374
Construct Triple-Completion Monitoring Well[2]	12	ea	$132,000	$ 1,584,000	$ 61,563	12	ea	$132,000	$ 1,584,000	$ 61,563
Equip Production and Monitoring Wells with SCADA	132	ea	$ 38,316	$ 5,057,712	$ 406,228	132	ea	$ 22,266	$ 2,939,106	$ 406,228
TOTALS				$ 82,182,672	$ 3,479,023				$37,775,759	$ 1,876,510

	150 TAF Fall Pumping, New Well Field					150 TAF Fall Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Construct and Equip Deep Irrigation Well	194	ea	$629,508	$122,124,552	$ 4,868,159	0	ea	$629,508	$ -	$ -
Construct and Equip Shallow Irrigation Well	0	ea	$382,008	$ -	$ -	81	ea	$382,008	$31,110,732	$ 1,315,313
Rehabilitate Existing Shallow Irrigation Well	0	ea[1]	$117,378	$ -	$ -	113	ea[1]	$117,378	$13,212,113	$ -
Purchase Existing Irrigation Well	0	ea	$132,330	$ -	$ -	113	ea	$132,330	$14,895,065	$ 1,191,698
Construct Triple-Completion Monitoring Well[2]	19	ea	$132,000	$ 2,560,800	$ 99,527	19	ea	$132,000	$ 2,560,800	$ 99,527
Equip Production and Monitoring Wells with SCADA	213	ea	$ 38,316	$ 8,176,634	$ 656,735	213	ea	$ 25,085	$ 5,353,092	$ 656,735
TOTALS				$132,861,986	$ 5,624,421				$67,131,801	$ 3,263,272

	150 TAF Summer & Fall Pumping, New Well Field					150 TAF Summer & Fall Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Construct and Equip Deep Irrigation Well	72	ea	$629,508	$ 45,324,576	$ 1,806,739	0	ea	$629,508	$ -	$ -
Construct and Equip Shallow Irrigation Well	0	ea	$382,008	$ -	$ -	0	ea	$382,008	$ -	$ -
Rehabilitate Existing Shallow Irrigation Well	0	ea[1]	$117,378	$ -	$ -	72	ea[1]	$117,378	$ 8,451,245	$ -
Purchase Existing Irrigation Well	0	ea	$132,330	$ -	$ -	72	ea	$132,330	$ 9,527,760	$ 762,280
Construct Triple-Completion Monitoring Well[2]	7	ea	$132,000	$ 950,400	$ 36,938	7	ea	$132,000	$ 950,400	$ 36,938
Equip Production and Monitoring Wells with SCADA	79	ea	$ 38,316	$ 3,034,627	$ 243,737	79	ea	$ 20,070	$ 1,589,567	$ 243,737
TOTALS				$ 49,309,603	$ 2,087,414				$20,518,971	$ 1,042,954

1. Quantity and unit costs are calculated by the proportion of wells requiring each rehabilitation activity (well rehabilitation, pump and motor rebuild, etc.).
2. It has been assumed that one monitoring well will be constructed for each 10 project wells, on average.

Annual maintenance costs for project wells, including monitoring wells and SCADA are summarized on Page 19 for each pumping scenario.

	300 TAF Summer Pumping, New Well Field					300 TAF Summer Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Deep Well Maintenance[3]	243	ea	$ 7,536	$ 1,831,248	$ 1,831,248	0	ea	$ 7,536	$ -	$ -
Shallow Well Maintenance[3]	0	ea	$ 5,286	$ -	$ -	243	ea	$ 5,286	$ 1,284,498	$ 1,284,498
Monitoring Well Maintenance[3]	24	ea	$ 1,200	$ 29,160	$ 29,160	24	ea	$ 1,200	$ 29,160	$ 29,160
SCADA Maintenance[3]	267	ea	$ 3,119	$ 833,577	$ 833,577	267	ea	$ 3,119	$ 833,577	$ 833,577
TOTALS					$ 2,693,985					$ 2,147,235

	150 TAF Summer Pumping, New Well Field					150 TAF Summer Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Deep Well Maintenance[3]	120	ea	$ 7,536	$ 904,320	$ 904,320	0	ea	$ 7,536	$ -	$ -
Shallow Well Maintenance[3]	0	ea	$ 5,286	$ -	$ -	120	ea	$ 5,286	$ 634,320	$ 634,320
Monitoring Well Maintenance[3]	12	ea	$ 1,200	$ 14,400	$ 14,400	12	ea	$ 1,200	$ 14,400	$ 14,400
SCADA Maintenance[3]	132	ea	$ 3,119	$ 411,643	$ 411,643	132	ea	$ 3,119	$ 411,643	$ 411,643
TOTALS					$ 1,330,363					$ 1,060,363

	150 TAF Fall Pumping, New Well Field					150 TAF Fall Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Deep Well Maintenance[3]	194	ea	$ 7,536	$ 1,461,984	$ 1,461,984	0	ea	$ 7,536	$ -	$ -
Shallow Well Maintenance[3]	0	ea	$ 5,286	$ -	$ -	194	ea	$ 5,286	$ 1,025,484	$ 1,025,484
Monitoring Well Maintenance[3]	19	ea	$ 1,200	$ 23,280	$ 23,280	19	ea	$ 1,200	$ 23,280	$ 23,280
SCADA Maintenance[3]	213	ea	$ 3,119	$ 665,490	$ 665,490	213	ea	$ 3,119	$ 665,490	$ 665,490
TOTALS					$ 2,150,754					$ 1,714,254

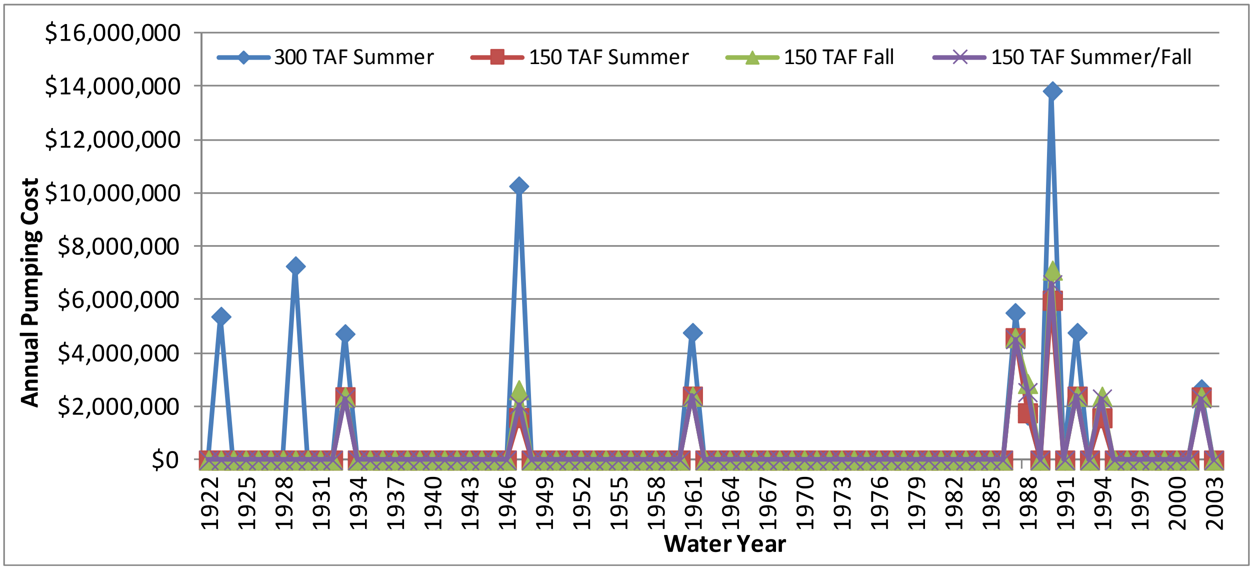
	150 TAF Summer & Fall Pumping, New Well Field					150 TAF Summer & Fall Pumping, Existing Well Field				
	Qty	Unit	Unit Cost	Total Cost	Annualized Cost	Qty	Unit	Unit Cost	Total Cost	Annualized Cost
Deep Well Maintenance[3]	72	ea	$ 7,536	$ 542,592	$ 542,592	0	ea	$ 7,536	$ -	$ -
Shallow Well Maintenance[3]	0	ea	$ 5,286	$ -	$ -	72	ea	$ 5,286	$ 380,592	$ 380,592
Monitoring Well Maintenance[3]	7	ea	$ 1,200	$ 8,640	$ 8,640	7	ea	$ 1,200	$ 8,640	$ 8,640
SCADA Maintenance[3]	79	ea	$ 3,119	$ 246,986	$ 246,986	79	ea	$ 3,119	$ 246,986	$ 246,986
TOTALS					$ 798,218					$ 636,218

3. Maintenance costs represent annual amounts estimated as a percent of initial capital cost.

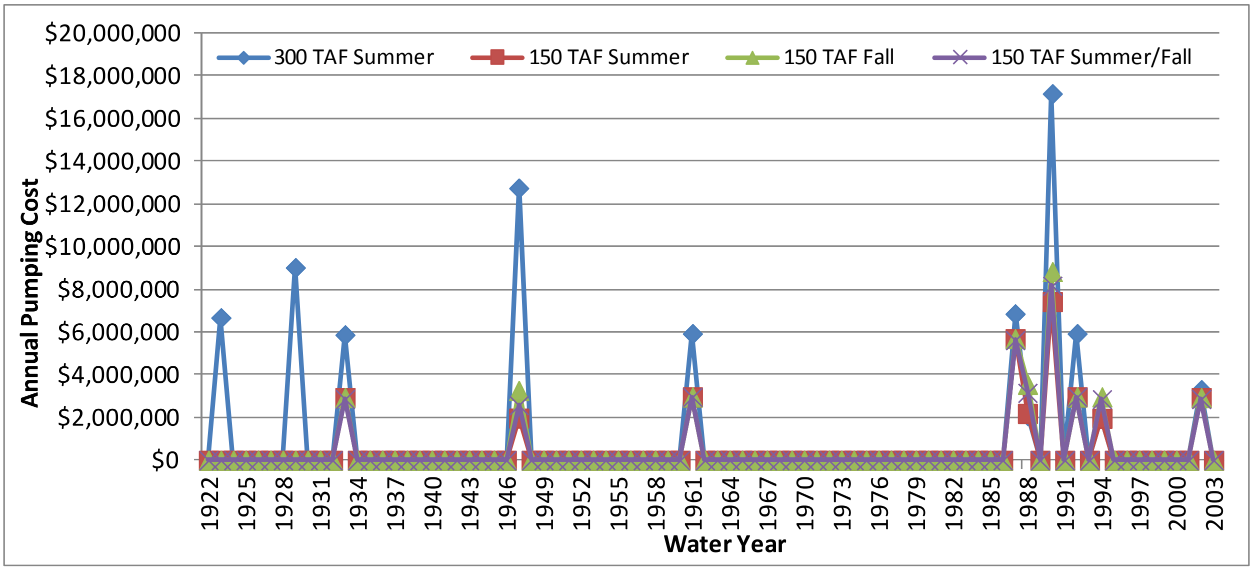
Annual Pumping Costs

Annual pumping costs were calculated based on pumped volumes and estimated cost per acre-foot pumped for shallow and deep production wells. Total pumping costs for the full study period are summarized in the table below. The time series of annual pumping costs for new well field pumping scenarios is shown in the following figure.

Pumping Scenario	Well Field	Pumping Costs	
		Total (full study period)	Average (years with pumping)
300 TAF Summer	New	$ 30,060,829	$ 5,010,138
	Existing	$ 37,321,899	$ 6,220,316
150 TAF Summer	New	$ 18,672,745	$ 3,112,124
	Existing	$ 23,183,070	$ 3,863,845
150 TAF Fall	New	$ 21,708,314	$ 3,618,052
	Existing	$ 26,951,868	$ 4,491,978
150 TAF Summer/Fall	New	$ 20,657,963	$ 3,442,994
	Existing	$ 25,647,809	$ 4,274,635



The time series of annual pumping costs for existing well field pumping scenarios is shown in the following figure.



As indicated, pumping costs tend to be greater for the existing well field scenarios as compared to the new well field scenarios. This is due to the lower aquifer having a greater specific capacity, which results in less pumping drawdown and required lift as compared to pumping from the shallow regional aquifer.

Project Operations Costs

The cost of operating the project was estimated based on the estimated level of effort required to operate the project and estimated salaries and overhead for project operators. Estimated operation costs for years with and without pumping are provided on the following page.

Estimated cost for project operations. Responsibilities include forecasting and scheduling project pumping according to program objectives and operating rules; coordination with USBR, DWR, and other agencies; and overall project management.

Estimated Time Required in Pumping Years

	Summer	Fall	Summer & Fall	
Pumping Duration (months):	6	5	9	(2 months added to account for ramp up/down)
Working Days per Month:	22			
Estimated Time Requirement (hr/day) During Pumping:	2		(25%)	
Estimated Time Requirement (hr/week) During Non-Pumping Period:	2			

	Summer	Fall	Summer & Fall
Total Hours Required per Year:	313	278	452
	15%	14%	22%
Base Salary:	$120,000		
Multiplier:	2.5		

	Summer	Fall	Summer & Fall
Total Cost (Pumping Years):	$ 45,966	$ 40,854	$ 66,401

Estimated Time Required in Non-Pumping Years

Estimated Time Requirement (hr/week) During Non-Pumping Period:	2

	Summer	Fall	Summer & Fall
Total Hours Required per Year:	104	104	104
	5%	5%	5%
Base Salary:	$120,000		
Multiplier:	2.5		

Project Monitoring Costs

Monitoring costs were estimated based on the estimated level of effort required for monitoring of water levels, groundwater modeling, managing pump operation to minimize or avoid impacts, and providing coordination and reporting, along with estimated salaries and overhead for project operators. Estimated monitoring costs for years with and without pumping are provided below.

Estimated cost for water level monitoring, feedback, and real-time program management. Responsibilities include conducting monitoring, operating and maintaining GW model, managing pump operation in real time to minimize or avoid impacts, conferring with appropriate authorities, and preparing periodic reports of project operations.

Estimated Time Required in Pumping Years

	Summer	Fall	Summer & Fall	
Monitoring Duration (months):	12	12	12	(assumes full year of monitoring in any year of operation)
Working Days per Month:	22			

					Hours per Week Required	
Task	Position	Salary	Multiplier	Hourly	Pumping Period	Non-Pumping Period
Water Level Monitoring	Eng. Tech	$60,000	2.5	$72.12	20	10
Data Quality Control	Eng. Tech	$60,000	2.5	$72.12	10	5
Monitor Pump Operation	Eng. Tech	$60,000	2.5	$72.12	10	0
Analysis of Monitoring Data	Engineer	$90,000	2.5	$108.17	20	4
Real Time Strategic Operation Decisions	Engineer	$90,000	2.5	$108.17	10	0
Confer with Appropriate Authorities	Engineer	$90,000	2.5	$108.17	2	0
Preparation of Monitoring and Operations Reports	Engineer	$90,000	2.5	$108.17	2	2

	Monthly Cost	
Position	Pumping Period	Non-Pumping Period
Engineering Technician	$12,500	$4,688
Engineer	$15,938	$2,813
TOTALS	$28,438	$7,500

	Annual Cost		
Position	Summer	Fall	S & F
Engineering Technician	$150,000	$150,000	$150,000
Engineer	$191,250	$191,250	$191,250
TOTALS	$341,250	$341,250	$341,250

Estimated Time Required in Non-Pumping Years

Task	Position	Salary	Multiplier	Hourly	Hours per Week
Water Level Monitoring	Eng. Tech	$60,000	2.5	$72.12	10
Data Quality Control	Eng. Tech	$60,000	2.5	$72.12	5
Monitor Pump Operation	Eng. Tech	$60,000	2.5	$72.12	0
Analysis of Monitoring Data	Engineer	$90,000	2.5	$108.17	4
Real Time Strategic Operation Decisions	Engineer	$90,000	2.5	$108.17	0
Confer with Appropriate Authorities	Engineer	$90,000	2.5	$108.17	0.5
Preparation of Monitoring and Operations Reports	Engineer	$90,000	2.5	$108.17	1

Position	Annual Cost
Engineering Technician	$56,250
Engineer	$30,938
TOTALS	$87,188

Annual GW Model Update

Task	Consultant Rate ($/hr)	Hours	Total
GW Model Update (incorporate new data, calibrate, operate, report)	$200	160	$32,000

Project Administrative and Legal Costs

Costs for administration of mitigation aspects of the program, including legal costs, were estimated based on the estimated level of effort required in pumping and non-pumping years, combined with estimated salaries and overhead for program administrators and legal staff. Estimated administrative and legal costs are summarized below.

Estimated cost for administration of mitigation aspects of the program. Costs will be incurred in greater amounts in pumping years, but residual effects of pumping will lead to a need for mitigation in non-pumping years as well.

Estimated Time Required in Pumping Years

	Summer	Fall	Summer & Fall
Mitigation Duration (months)	12	12	12

Working Days per Month: 22

					Hours per Week Required	
Task	Position	Equiv. Salary	Multiplier	Hourly	Pumping Period	Non-Pumping Period
Interface with Monitoring Team; Review Data	Manager	$120,000	2.5	$144.23	2	2
Conduct Outreach Regarding Observed Impacts	Manager	$120,000	2.5	$144.23	2	2
Handle Disputes Over Impacts	Manager	$120,000	2.5	$144.23	4	4
Legal Support	Attorney	$250,000	2.5	$300.48	5	5

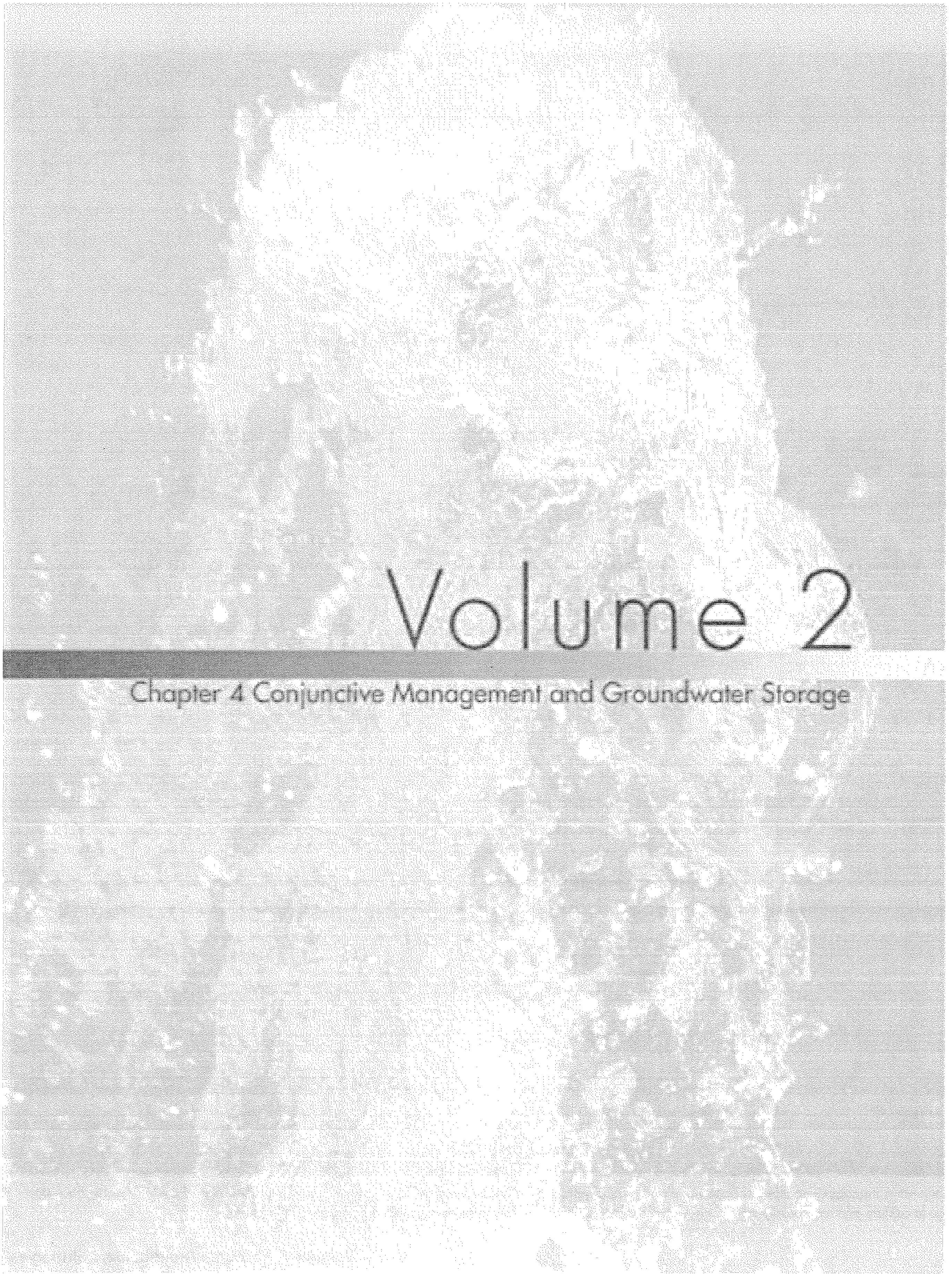
	Monthly Cost	
Position	Pumping Period	Non-Pumping Period
Manager	$5,000	$5,000
Attorney	$6,510	$6,510
TOTALS	$11,510	$11,510

	Annual Cost		
Position	Summer	Fall	S & F
Manager	$60,000	$60,000	$60,000
Attorney	$78,125	$78,125	$78,125
TOTALS	$138,125	$138,125	$138,125

Estimated Time Required in Non-Pumping Years

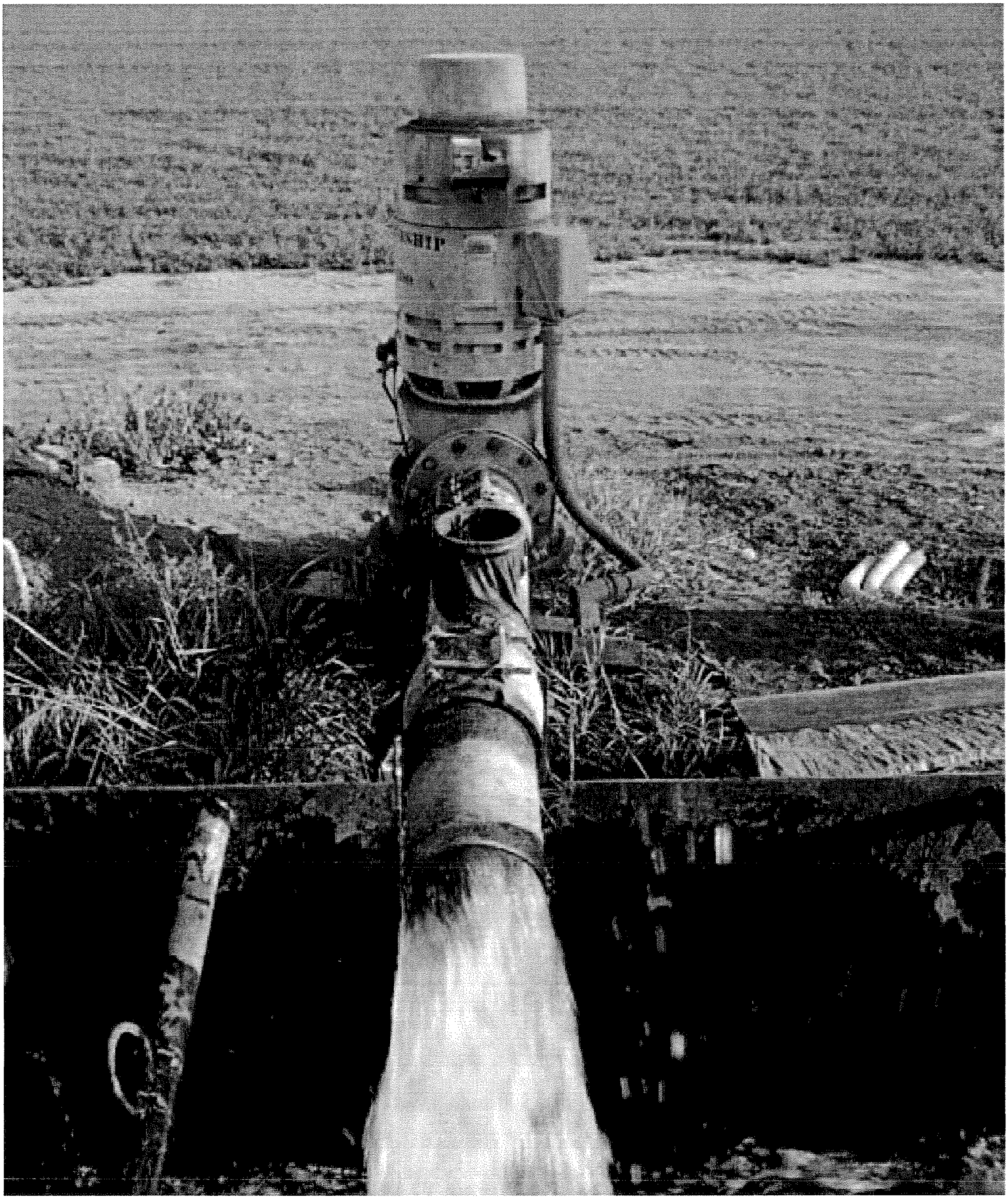
Task	Position	Salary	Multiplier	Hourly	Hours per Week
Interface with Monitoring Team; Review Data	Manager	$120,000	2.5	$144.23	1
Conduct Outreach Regarding Observed Impacts	Manager	$120,000	2.5	$144.23	1
Handle Disputes Over Impacts	Manager	$120,000	2.5	$144.23	1
Legal Support	Attorney	$250,000	2.5	$300.48	1

Position	Annual Cost
Manager	$22,500
Attorney	$15,625
TOTALS	$38,125



Volume 2

Chapter 4 Conjunctive Management and Groundwater Storage



Conjunctive management allows surface water and groundwater to be managed in an efficient manner by taking advantage of the ability of surface storage to capture and temporarily store storm water and the ability of aquifers to serve as long-term storage. (DWR photo)

Chapter 4 Conjunctive Management and Groundwater Storage

Conjunctive management is the coordinated operation of surface water storage and use, groundwater storage and use, and conveyance facilities to meet water management objectives. Although surface water and groundwater are sometimes considered to be separate resources, they are connected by the hydrologic cycle. Conjunctive management allows surface water and groundwater to be managed in an efficient manner by taking advantage of the ability of surface storage to capture and temporarily store storm water and the ability of aquifers to serve as long-term storage.

There are three primary components to a conjunctive management project when the primary objective is to increase average water deliveries. The first is to recharge groundwater when surface water is available to increase groundwater storage (see Box 4-1). In some areas this is accomplished by reducing groundwater use and substituting it with surface water, allowing natural recharge to increase groundwater storage (also called in-lieu recharge). The second component is to switch to groundwater use in dry years when surface water is scarce. The third component is to have an ongoing monitoring program to evaluate and allow water managers to respond to changes in groundwater, surface water, or environmental conditions that could violate management objectives or impact other water users. Together these components make up a conjunctive management project. Conjunctive management projects may have other objectives in place of or in addition to improving average water deliveries. These other objectives may include improving water quality, reducing salt water intrusion, and reducing groundwater overdraft.

Other topics in the Water Plan that are related to conjunctive management include the strategies on Groundwater Remediation / Aquifer Remediation, Recharge Areas Protection, Water Transfers, and System Reoperation.

Conjunctive Management in California

Conjunctive management has been practiced in California to varying degrees since the Spanish mission era. The first known artificial recharge of groundwater in California occurred in Southern California during the late 1800s and is now used as a management tool in many areas. Two examples illustrate the types of conjunctive management under way on a regional and local scale. In Southern California, including Kern County, conjunctive management has increased average-year water deliveries by more than 2 million acre-feet (AGWA, 2000). Over a period of years, artificial recharge in these areas has increased the water now in groundwater storage by about 7 million acre-feet.

Box 4-1 Groundwater Recharge

Groundwater recharge is the movement of surface water from the land surface, through the topsoil and subsurface, and into de-watered aquifer space. Recharge occurs naturally from precipitation falling on the land surface, from water stored in lakes, and from creeks and rivers carrying storm runoff. Recharge also occurs when water is placed into constructed recharge ponds (also called spreading basins), when water is injected into the subsurface by wells, and when water is released into creeks and rivers beyond what occurs from the natural hydrology (for example, by releases of imported water). These later examples of recharge are often called artificial, intentional, managed or induced recharge. Significant amounts of recharge can also occur either intentionally or incidentally from applied irrigation water and from water placed into unlined conveyance facilities.

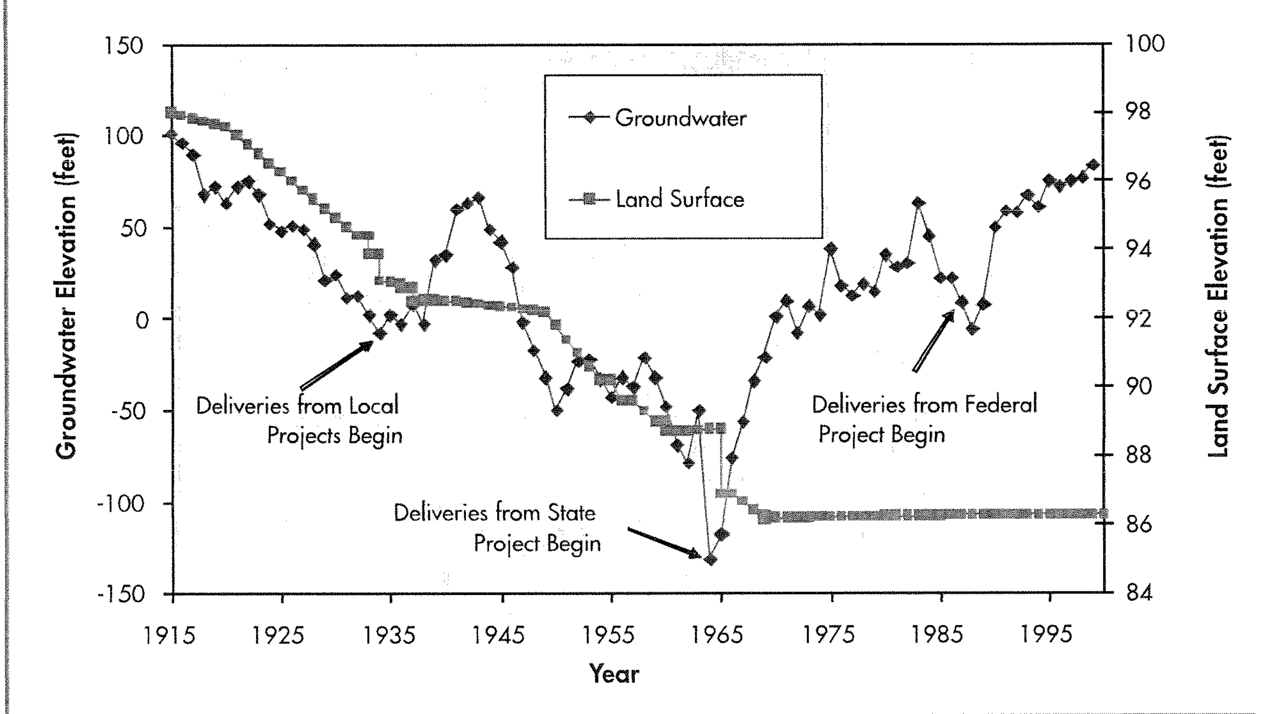
Santa Clara Valley Water District releases local supplies and imported water into more than 20 local creeks for artificial instream recharge and into more than 70 recharge ponds with an average annual recharge capacity of 138,000 acre-feet. Conjunctive management has virtually stopped land subsidence caused by heavy groundwater use and has allowed groundwater levels to recover to those of the early 1900s (see Figure 4-1).

There is no comprehensive statewide data on the planning and implementation of conjunctive management at the local agency level, but DWR's Conjunctive Water Management Program provides an indication of the types and magnitude of projects that water agencies are pursuing. In fiscal years 2001 and 2002 the program awarded more than $130 million in grants and loans to leverage local and regional investment in projects throughout California with total costs of about $550 million (see Figure 4-2).

Potential Benefits from Conjunctive Management

Conjunctive management is used to improve water supply reliability, to reduce groundwater overdraft and land subsidence, to protect water quality, and to improve environmental conditions. Conservative estimates of additional implementation of conjunctive management indicate the potential to increase average annual water deliveries throughout the state by 500,000 acre-feet with 9 million acre-feet of "new" groundwater storage[1]. New storage includes both reoperation of existing groundwater storage and recharging water into de-watered aquifer space. More aggressive estimates from screening level studies indicate the potential to increase average annual water deliveries by 2 million acre-feet with about 20 million acre-feet of new storage. The more aggressive estimates are based on assumptions that require major reoperation of existing surface water reservoirs and

Figure 4-1 Relationship between groundwater elevations and land subsidence in Santa Clara County



Conjunctive management in Santa Clara County has virtually stopped land subsidence caused by heavy groundwater use, allowing groundwater to recover to early 1900s levels. Santa Clara Valley Water District releases local supplies and imported water into creeks for artificial instream recharge and into recharge ponds.

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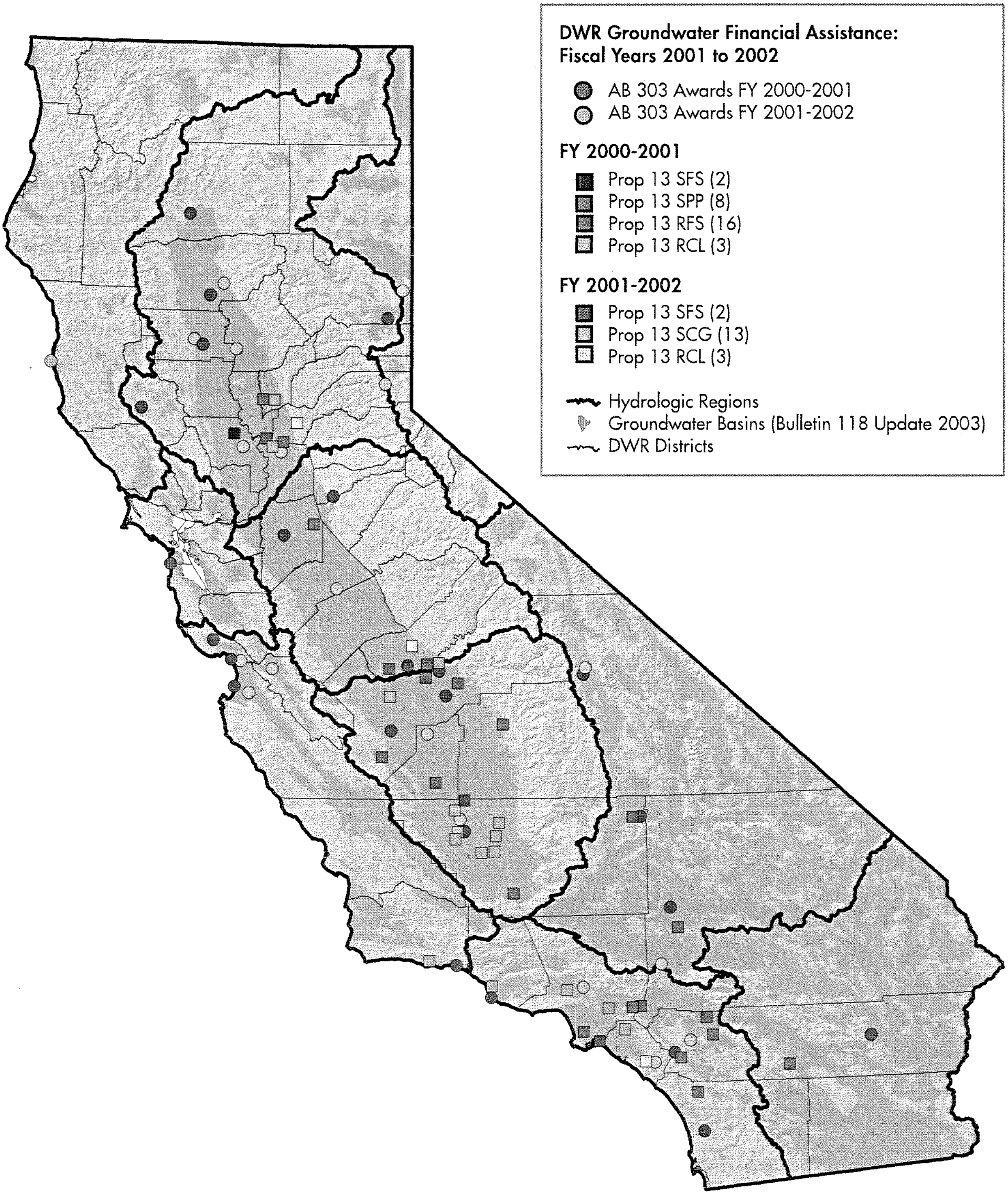
[1] Information in this section was derived from five sources: 1) Proposition 13 Groundwater Storage Applications to DWR for fiscal year 2001-2002, 2) A 2000 report by the Association of Groundwater Agencies entitled, "Groundwater and Surface Water in Southern California", 3) A 1998 report by the Natural Heritage Institute entitled, "Feasibility Study of a Maximal Program of Groundwater Banking", 4) A 2002 report by the Natural Heritage Institute entitled, "Estimating the Potential for In-Lieu Conjunctive Management in the Central Valley", 5) A 2002 report by the U.S. Army Corps of Engineers report entitled, "Conjunctive Use for Flood Protection".

Figure 4-2 Department of Water Resources, Division of Planning and Local Assistance groundwater grant and loan programs: AB303 and Proposition 13, FY's 2001-2002



In fiscal years 2001 and 2002, DWR's Conjunctive Water Management Program awarded more than $130 million in grants and loans to leverage local and regional investment in projects throughout California with total costs of about $550 million.

groundwater storage to achieve the benefits and do not fully consider the conveyance capacity constraints for exports from the Delta and other conveyance facilities.

The potential benefits from additional conjunctive management are highly dependent on adequate water quality and the ability to capture, convey, and recharge surface water. The above estimates are based on increases in local water deliveries from individual projects with project specific sources of recharge supply and do not necessarily reflect a statewide increase in supply reliability. An increase in statewide supply reliability only occurs when the individual projects use water that would otherwise not be used by other water users or that is not needed for regulatory requirements such as water quality, fish and wildlife, and navigation. Expanding existing or developing new storage or conveyance infrastructure can increase the flexibility and ability to conduct conjunctive management projects. It is also possible to reoperate the existing system and to improve the underlying operational conditions to overcome these constraints.

In addition to water supply benefits, conjunctive management can provide environmental benefits when recharge basins are designed to be compatible with wildlife habitat, such as using natural floodplains and wetlands as recharge areas. Re-operation of surface water storage and using the water conjunctively with groundwater can avoid impacts to aquatic species by allowing better management of instream flow and water quality conditions.

Potential Costs of Conjunctive Management

Grant applications from DWR's fiscal year 2001-2002 Conjunctive Water Management Program show project costs ranging from $10 to $600 per acre-foot of increase in average annual delivery. The wide range of costs is due to many factors including project complexity, regional differences in construction and land costs, availability and quality of recharge supply, availability of infrastructure to capture, convey, recharge, and extract water, intended use of water, and treatment require-

Box 4-2 Conjunctive Management Case Example: Orange County Groundwater Replenishment System

The Groundwater Replenishment (GWR) System is a groundwater management and water supply project jointly sponsored by the Orange County Water District (OCWD) and Orange County Sanitation District (OCSD). The project will take highly treated urban wastewater and treat it to beyond drinking water standards using advanced membrane purification technology. The water will be used to expand an existing underground seawater intrusion barrier by injecting the water into the groundwater basin along the coast. Extraction wells throughout the basin will draw potable water for municipal and industrial uses.

The GWR System will provide many benefits to Orange County and California, including:

- Supplements existing water supplies by providing a new, reliable, high-quality source of water to recharge the Orange County Groundwater Basin and protect the basin from further degradation because of seawater intrusion.
- Reduces the amount of treated wastewater released into the ocean and delays the need for another ocean outfall.
- Decreases Orange County's reliance on imported water from Northern California and the Colorado River.
- Helps drought-proof Orange County using a locally-controlled project.
- Reduces mineral build up in Orange County's groundwater by providing a new source of ultra-pure water to blend with other sources, including imported water.
- Uses about half the energy of imported water supplies.

Implementation of the GWR System will be phased. The schedule calls for Phase 1 of the proposed project to produce up to 72,000 acre-feet per year of recycled water for groundwater recharge to begin operation in 2007. The total cost of the project is estimated to be $453 million. The unit cost of the supply is $516 per acre-foot.

ments. In general, urban uses can support higher project costs than agricultural uses. The average project cost of all applications received by DWR is $110 per acre-foot of increase in average annual delivery. This average unit cost translates to statewide implementation costs of approximately $1.5 billion for the conservative level of implementation and $5 billion for the aggressive implementation[2].

Major Issues Facing Additional Conjunctive Management

Lack of Data

There is rarely a complete regional network to monitor groundwater levels, water quality, land subsidence, or the interaction of groundwater with surface water and the environment. Data is needed to evaluate conditions and trends laterally over an area, vertically at different depths, and over time. Also, there is often a reluctance of individuals who own groundwater monitoring or supply wells to provide information or allow access to collect additional information. The result is that decisions are often made with only approximate knowledge of the system. This uncertainty can make any change in groundwater use controversial. Additional investment in a monitoring network and data collection can help reduce this uncertainty, but must be done in accordance with a groundwater management plan that is acceptable to stakeholders in the basin.

Infrastructure and Operational Constraints

Physical capacities of existing storage and conveyance facilities are often not large enough to capture surface water when it is available in wet years. Operational constraints may also limit the ability to use the full physical capacity of facilities. For example, permitted export capacity and efforts to protect fisheries and water quality in the Delta often limit the ability to move water to groundwater banks south of the Delta. Facilities that are operated for both temporary storage of flood water and groundwater recharge require more frequent maintenance to clean out excessive sediment often present in flood water.

Surface Water and Groundwater Management

In California, water management practices and the water rights system treat surface water and groundwater as two unconnected resources. In reality, there is often a high degree of hydrologic connection between the two. Under predevelopment conditions many streams received dry weather base flow from groundwater storage, and streams provided wet weather recharge to groundwater storage. Water quality and the environment can also be influenced by the interaction between surface water and groundwater. Failure to understand these connections can lead to unintended impacts. For example, studies by the University of California, Davis, indicate that long term groundwater pumping in Sacramento County has reduced or eliminated dry season base flow in sections of the Cosumnes River with potential impacts to riparian habitat and anadromous fish.

In California, authority is separated among local, State and federal agencies for managing different aspects of groundwater and surface water resources. Several examples highlight this issue: 1) SWRCB regulates surface water rights dating from 1914, but not rights dating before 1914; 2) SWRCB also regulates groundwater quality, but not the rights to use groundwater; 3) County groundwater ordinances and local agency groundwater management plans often only apply to a portion of the groundwater basin, and those with overlapping boundaries of responsibility do not necessarily have consistent management objectives; and 4) Except in adjudicated basins, individuals have few restrictions on how much groundwater they can use, provided the water is put to beneficial use on the overlying property. Failure to integrate water management across jurisdictions makes it difficult to manage water for multiple benefits and provide for sustainable use including the ability to identify and protect or mitigate potential impacts to third parties, ensure protection of legal rights of water users, establish rights to use vacant aquifer space and banked water, protect the environment, recognize and protect groundwater recharge and discharge areas, and protect public trust resources. The Protecting Recharge Areas and Urban Runoff Management strategies describe how land use planning can affect groundwater recharge and groundwater quality.

Water Quality

Groundwater quality can be degraded by naturally occurring or human introduced chemical constituents, low quality recharge water, or chemical reactions caused by mixing water of differing qualities. Protection of human health, the environment, and groundwater quality are all concerns for programs that recharge urban runoff or reclaimed/recycled water. The intended end use of the water can also influence the implementation of conjunctive management projects. For example, agriculture can generally use water of lower quality than needed for urban use, but certain crops can be sensitive to some constituents like boron.

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[2] Cost estimates are extrapolated from Proposition 13 Groundwater Storage Applications to DWR for fiscal year 2001-2002. Cost estimates assume that the supply benefit is not restricted by Delta export constraints or conveyance capacity.

New and changing water quality standards and emerging contaminants add uncertainty to implementing conjunctive management projects. A water source may, at the time it is used for recharge, meet all drinking water quality standards. Over time, however, detection capabilities improve and new or changed water quality standards become applicable. As a result, contaminants that were not previously identified or detected may become future water quality problems creating potential liability uncertainties. In some cases, conjunctive management activities may need to be coordinated with groundwater clean up activities to achieve multiple benefits to both water supply and groundwater quality.

Environmental Concerns

Environmental concerns related to conjunctive management projects include potential impacts on habitat, water quality, and wildlife caused by shifting or increasing patterns of groundwater and surface water use. For example, floodwaters are typically considered "available" for recharge. However, flood flows serve an important function in the ecosystem. Removing or reducing these peak flows can negatively impact the ecosystem. A key challenge is to balance the instream flow and other environmental needs with the water supply aspects of conjunctive management projects. There may also be impacts from construction and operation of groundwater recharge basins and new conveyance facilities.

Funding

There is generally limited funding to develop the infrastructure and monitoring capability for conjunctive management projects. This includes funding to develop and implement groundwater management plans, to study and construct conjunctive management projects, and to track, both statewide and regionally, changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, changes in surface water flow, surface water quality, and the interaction and interrelated nature of surface water and groundwater.

Recommendations to Help Promote Additional Conjunctive Management

1. Local water management agencies should coordinate with other agencies that are involved in activities that might affect long term sustainability of water supply and water quality within the basin or adjacent to the basin. Such regional coordination will take different forms in each area because of dissimilar political, legal, institutional, technical, and economic constraints and opportunities, but will likely include agencies with authority over managing groundwater and surface water quantity and quality, land use planning, human health, and environmental protection. Regional groundwater management plans should be developed with assistance from an advisory committee of stakeholders to help guide the development, educational outreach, and implementation of the plans.
2. Continue funding for local groundwater monitoring and management activities and feasibility studies that enhance the coordinated use of groundwater and surface water. Additional monitoring and analysis is needed to track, both statewide and regionally, changes in groundwater levels, groundwater flows, groundwater quality (including the location/spreading of contaminant plumes), land subsidence, changes in surface water flow, surface water quality, and the interaction and interrelated nature of surface water and groundwater. There is a need to develop comprehensive data and data management systems to track existing, proposed, and potential conjunctive management projects throughout the state and identify and evaluate regional and statewide implementation constraints including availability of water to recharge, ability to convey water from source to destination, water quality issues, environmental issues, and costs and benefits.
3. Give priority for funding and technical assistance to conjunctive management projects that are conducted in accordance with a groundwater management plan, increase water supplies, and have other benefits including the sustainable use of groundwater, maintaining or improving water quality, and enhancing the environment. Additional preference should be given for projects conducted in accordance with a regional groundwater management plan. In addition, allow funding for projects that make use of wet season/dry season supply variability, not just wet-year/dry-year variability.
4. Assess groundwater management throughout the state to provide an understanding of how local agencies are implementing actions to use and protect groundwater, an understanding of which actions are working at the local level and which are not working, and how State programs can be improved to help agencies prepare effective groundwater management plans.
5. Improve coordination and cooperation among local, State, and federal agencies with differing responsibilities for groundwater and surface water management and monitoring to facilitate conjunctive management, to ensure efficient

use of resources, to provide timely regulatory approvals, to prevent conflicting rules or guidelines, and to promote easy access to information by the public.

6. Encourage local groundwater management authorities to manage the use of vacant aquifer space for artificial recharge and to develop multi-benefit projects that generate source water for groundwater storage by capturing water that would otherwise not be used by other water users or the environment. For example, through reservoir reoperation, water recycling and reuse, and water conservation.
7. Work with wildlife agencies to streamline the environmental permitting process for the development of conjunctive management facilities, like recharge basins, when they are designed with pre-defined benefits or mitigation to wildlife and wildlife habitat.

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BDCP1738.

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September 19, 2013

Re: Independent Panel Review of the Bay Delta Conservation Plan

Dear Interested Stakeholder:

The attached report was prepared by an independent panel of experts convened by Dr. Jeff Mount for American Rivers and The Nature Conservancy to assist in our deliberations regarding the Bay Delta Conservation Plan. Dr. Mount assembled a balanced, interdisciplinary, and objective group of experts with long experience in the San Francisco Bay-Delta estuary to conduct this review of the March 2013 BDCP Administrative Draft and associated documents released during the Spring of 2013. This report will now join a growing library of independent reviews of efforts to resolve the Delta crisis.

The opinions, analyses, and recommendations provided in the report are solely those of the authors. Our organizations will use the information in the report along with our own analysis of BDCP to develop a proposal for increasing the probability that BDCP will substantially improve environmental conditions in the Delta. This report does not represent the position of American Rivers or the Nature Conservancy.

American Rivers and The Nature Conservancy have been active participants in the BDCP planning process for the last seven years. Our organizations have not taken a formal position in support of the proposed project described in the administrative draft of the BDCP, but we are fully committed to continue our work in good faith to develop a conservation plan for the Delta ecosystem that advances the co-equal goals of ecosystem restoration and water supply reliability. The status quo condition in the Delta is unacceptable, and without action, will result in the inexorable decline of the Delta ecosystem and the species it supports.

Please direct questions regarding the report to Leo Winternitz or John Cain at lwinternitz@TNC.ORG and jcain@americanrivers.org. Thank you for your consideration.

Sincerely:

Leo Winternitz

Leo Winternitz
Senior Advisor - Water Program
The Nature Conservancy

John Cain
Conservation Director
American Rivers

BDCP1738.

PANEL REVIEW OF THE DRAFT BAY DELTA CONSERVATION PLAN:

PREPARED FOR THE NATURE CONSERVANCY AND AMERICAN RIVERS

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Technical support provided by NewFields, Inc.

September 2013

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Preface

The Bay-Delta Conservation Plan is more than 15,000 pages long and covers a wide range of issues ranging from water supply, new facility construction, aquatic and terrestrial ecosystem management, governance and costs. Few outside of the handful of people deeply involved in BDCP actually know what is in the document due to its imposing size. This is particularly true for the various stakeholder groups who lack either the staff or the technical capacity to review the document and to evaluate the complex analyses that underpin it.

Saracino & Mount, LLC, was asked to assemble a panel of independent experts to review portions of the Plan to help guide decision-making by two non-governmental organizations: The Nature Conservancy and American Rivers. Guided by a narrow set of questions about how the Plan would impact water supply and endangered fishes, the panel reviewed the Plan documents and conducted analyses of data provided by the project consultants. The following document is a summary of our results.

It is important that this analysis not be over-interpreted. We do not endorse or reject the Plan. We only assess effectiveness of various conservation measures, guided by narrowly targeted questions. In addition, we make a handful of modest proposals to improve the performance of the Plan, particularly for issues of concern to the two non-governmental organizations. Thus, the scope of this review is quite limited.

The authors wish to thank the S.D. Bechtel, Jr. Foundation for its generous support. The staff of The Nature Conservancy and American Rivers provided abundant time and energy as we scoped this review. Jennifer Pierre, Armin Munevar, Chandra Chillmakuri, and Laura King-Moon provided voluminous data, answered our many questions and addressed our concerns. Spreck Rosecrans and Drs. Peter Moyle and Jay Lund provided comment on portions of the manuscript, although their comments do not constitute formal peer review. All errors of omission or commission are our own.

Jeff Mount, Panel Chair

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Executive Summary

Two non-governmental organizations, The Nature Conservancy (TNC) and American Rivers (AR), are evaluating their options for engagement with the Bay Delta Conservation Plan (BDCP). If approved, the Plan would become a Habitat Conservation Plan (HCP) under the federal Endangered Species Act and a Natural Communities Conservation Plan (NCCP) under California law. The purpose of the Plan is to allow for construction of new water diversion facilities in the Sacramento-San Joaquin Delta while also protecting aquatic and terrestrial species that may be adversely affected by the project and accompanying changes in the State Water Project (SWP) and Central Valley Project (CVP) operations. The Plan also includes habitat restoration and a commitment to assist in the conservation and recovery of species that are listed for protection under the federal and state Endangered Species Acts.

With financial support from the S.D. Bechtel, Jr. Foundation, Saracino and Mount, LLC, convened an independent panel of experts, with technical support from NewFields, Inc., to evaluate portions of the Plan. The panel, working jointly with TNC and AR, developed a series of technical and legal questions about the Plan. This report provides answers to these questions, along with limited recommendations on how to improve BDCP.

To simplify analysis, this review focuses on conditions for federally listed fishes during the Early Long Term (ELT), a decade after a permit would be issued (approximately year 2025). These are described in detail in the BDCP Effects Analysis and accompanying Environmental Impact Statement/Environmental Impact Report. We compared the performance of three different scenarios: a No Action Alternative (NAA) where no new North Delta diversion facility is constructed, a High Outflow Scenario (HOS) where the facilities are operated in a way that allows for occasional high spring and fall outflows, and a Low Outflow Scenario (LOS) with lower spring and fall outflows. The review also emphasizes in-Delta and Sacramento River watershed conditions during the ELT, with less attention to San Joaquin River conditions and fishes.

Although multiple data sources were used in this analysis, most hydrologic data came from CALSIM simulations conducted by BDCP consultants. The Panel strongly cautions about the conclusions drawn from these simulations. Flow simulations have three compounding uncertainties that can lead to significant error: (1) uncertainty in system understanding and future conditions, (2) model uncertainties (particularly the relationships between 1-, 2-, and 3-dimensional models), and (3) behavioral/regulatory uncertainty where the models cannot capture the scope of human behavior in operating the projects under various conditions. These uncertainties, which are not described in BDCP documents well, makes all of our conclusions contingent on the projects *actually being operated as simulated.*

Do Operations Shift Delta Exports from Dry to Wet Years?

The BDCP calls for increasing exports in wet years and reducing them in dry years, taking advantage of the increased operational flexibility provided by two points of diversion. This would reduce stress on Delta ecosystems during drier periods. Our analysis of simulation data suggests that while there is some increase in flexibility, export operations are highly constrained by upstream consumptive uses, regulations that cover reservoir operations, and flow and water quality standards. This greatly limits the anticipated benefit associated with operation of the dual facilities. Despite these limitations, as modeled, there is an increase in exports in wet years. In most dry years there are no substantial changes over NAA conditions. However, significant improvements in outflow and Old and Middle River (OMR) conditions occur in some dry years. We were unable to identify the regulatory or operational requirements that would lead to this.

Are Impacts of the North Delta Facility Fully Assessed and Mitigated?

The Plan identifies multiple near- and far-field effects of the new North Delta facility. Based on our review of the Effects Analysis, the Plan appears to have properly identified the most significant effects and uses standard models to assess them. Outmigrating juvenile winter-run and spring-run Chinook salmon will be most heavily affected, leading, in the absence of mitigation, to significant losses. The Plan identifies multiple mitigation strategies, including pulse flow management, predator control, entrainment reduction, non-physical barriers, real-time operations and development of alternative migration pathways (Yolo Bypass). With the exception of benefits from diverting juveniles onto the Yolo Bypass, all of these mitigation approaches have high uncertainties. Done well and successfully, however, they appear to offset the losses associated with operation of the North Delta facility. The HOS appears most protective of conditions upstream of the Delta and adjacent to the new facility. However, mitigation actions are unlikely to contribute significantly to recovery of these species. Additionally, successful mitigation is likely to occur only if there is a robust adaptive management and real-time operations program. The Plan provides neither.

Are In-Delta Conditions Significantly Improved for Smelt?

We evaluated the modeling results in the Plan and conducted our own modeling to evaluate how changes in conditions would affect delta and longfin smelt. As noted, we are concerned that anomalously positive (or less negative) OMR flows and high Delta outflows that are modeled during some drier years would not actually occur in real operations. However, if these changes were to occur we find modest to significant improvement in in-Delta conditions for smelt, particularly delta smelt. Improvements in OMR flows under HOS and LOS result in substantial decreases in entrainment, leading to significant increases in long-term survival percentages for delta smelt. However, increases in spring and fall outflow under HOS lead to small increases in longfin smelt abundance and modest improvements in delta smelt recruitment.

Will Pelagic Fishes Benefit from Floodplain and Tidal Marsh Restoration?

The Plan properly identifies food limitation as a significant stressor on smelt populations in the Delta. The Plan proposes to address this issue by restoring physical habitat to help subsidize pelagic food webs. Based on simple modeling and comparison with other systems, we find that restored floodplains and tidal marshes are unlikely to make a significant contribution to smelt rearing habitat conditions. Tidal marshes can be sinks or sources of food, with most appearing to be sinks for zooplankton. The Plan appears to be too optimistic about the benefits of tidal marsh and floodplain restoration. However, there is likely to be benefit where fishes have direct access to productivity, such as in Cache Slough. In addition, although benefits for listed pelagic fishes are low, there are broad benefits of restoration for many aquatic and terrestrial species covered by the Plan.

Does the Plan Provide an Effective Governance Structure?

We reviewed the proposed BDCP governance structure to evaluate its likely effectiveness in meeting the Plan's goals and objectives. Implementation of BDCP would be overseen by an Authorized Entity Group (AEG) comprising the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation (USBR), and the state and federal water contractors if they are issued incidental take permits pursuant to the BDCP. A Permit Oversight Group (POG), consisting of the U.S. Fish and Wildlife Service (USFS), the National Marine Fisheries Service (NMFS), and the California Department of Fish and Wildlife (CDFW), would monitor implementation of the Plan and compliance with the biological objectives and conservation requirements. The draft BDCP includes a 50-year "no surprises" guarantee, as well as other regulatory assurances. We found that, when examined in detail, the draft BDCP blurs the lines between implementation and regulation and grants the permittees unusual decision authority. Additionally, the regulatory assurances in the Plan, especially the "no-surprises" policy, place undue financial responsibilities on the state and federal governments if certain modifications to the Plan become necessary during its 50-year term. Given the complexity of the Delta ecosystem, predicted changes in hydrology, anticipated changes in the Delta not included in the Plan, and significant scientific uncertainties, Plan modifications are likely to be needed in the future.

Is There a Robust Science and Adaptive Management Plan for BDCP?

The Plan is committed to adaptive management in order to address the high uncertainties. Most of the unresolved issues in the Plan are to be resolved at a future date through adaptive management. A "decision tree" approach is proposed to resolve conflicts over starting operations. We found that the governance structure, whereby the AEG may exercise veto authority over changes to the biological objectives and conservation measures, is likely to create disincentives for adaptive management. In addition, a proposed consensus-based Adaptive Management Team made up of POG, AEG, and scientific community members creates conflicting relationships between decision-makers and providers of key information. The limited information available about the science program suggests that BDCP proposes to develop a wholly new science program that is not integrated, but should be, with existing programs. Finally, our review of the "decision tree" process indicates that it is unlikely to achieve the goal of significantly reducing uncertainties before the North Delta facility is constructed and ready for operation.

Recommendations

Based on answers to these six questions, the Panel formulated a list of nine recommendations for improving BDCP.

- All parties need to recognize the model uncertainties in BDCP and factor that into decision-making. It is unlikely that actual operations will follow simulated operations.
- Given the high uncertainty over mitigation for the North Delta facility, all mitigation efforts should be in-place and tested *before* the facility is completed. This includes completion of the Fremont Weir modifications on the Yolo Bypass as well as large scale, significant experiments in real-time flow management, predator control and non-physical barriers.
- The improvements in long-term survival percentages for delta smelt in response to changes in OMR need to be more rigorously evaluated, particularly in light of uncertainties over operations. If further examination supports these findings, operational rules should be developed that insure that the anomalous, significantly improved drier-period OMR and outflow conditions occur.
- The limited benefit derived from changes in outflow under HOS requires a second look at options for significant increases in outflow, including finding sources of water outside the direct control of BDCP.
- Although we find that marsh and floodplain restoration is unlikely to create the benefits for pelagic fishes described in the Plan, this can only be resolved through experimental restoration projects. These projects need to be designed and implemented rapidly to resolve this issue.
- Substantial revision of BDCP's governance structure is needed. This includes giving full regulatory authority to the POG, while limiting their involvement in implementation.
- To address high uncertainties about project performance and future conditions, instead of a 50-year permit, there should be renewable "no surprises" guarantees issued every ten years based on conditions at the time and prior performance.
- An adaptive management program needs to be developed that has the capacity and authority to conduct adaptive management experiments and effectively use outcomes to revise and improve future actions..
- A well-funded BDCP science program needs to be developed that is integrated with existing Delta science programs. The best opportunity for integration lies with the current efforts to update the Delta Science Program.

Chapter 1: The Bay Delta Conservation Plan and Charge to the Panel

Introduction

The Bay Delta Conservation Plan (BDCP) is being developed to meet endangered species act permit requirements for operations of the Federal Central Valley Project (CVP) and the State Water Project (SWP) within the Sacramento-San Joaquin Delta. The Plan includes proposals for new points of diversion in the North Delta, new operations criteria, extensive floodplain and tidal marsh restoration, and new governance, oversight and adaptive management programs. The Plan applicants are seeking Habitat Conservation Plan (HCP)/Natural Communities Conservation Plan (NCCP) permits that will guide water exports and habitat management for 50 years.

The Bay Delta Conservation Plan is the most complex HCP/NCCP permit application ever attempted. Development of the Plan has been funded principally by state and federal water contractors and has been on-going for more than 5 years. In Spring 2013, select chapters of the Administrative Draft of BDCP were serially released for public review[1]. An Administrative Draft of the EIS/EIR for the Plan was released in May of 2013[2].

At the request of The Nature Conservancy California and American Rivers—two non-governmental organizations engaged in the BDCP process—an independent panel of five experts (Text Box 1.1) was assembled to assist in technical review of BDCP documents. The panel was asked to answer a suite of questions about the Plan to help inform decisionmaking by American Rivers and The Nature Conservancy. The panel was assembled and managed by Saracino & Mount, LLC, under contract from the S.D. Bechtel, Jr. Foundation Water Program. NewFields, Inc. provided support for the panel, including data retrieval, analysis and presentation. This report summarizes the conclusions of the work of this panel.

Guiding Questions

Two planning meetings were held between Saracino & Mount, LLC and staff of American Rivers and The Nature Conservancy. An initial list of more than 40 questions were developed that were germane to decisions that the organizations

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[1] This report assumes that the reader is familiar with the Sacramento-San Joaquin Delta and on-going efforts to manage water supply and ecosystems to meet the co-equal goals prescribed in the 2009 Delta Reform Act. A summary of conditions in the Delta and other issues can be found at: http://baydeltaconservationplan.com/Home.aspx

[2] http://baydeltaconservationplan.com/Library/DocumentsLandingPage/EIREISDocuments.aspx

needed to make about future engagement with BDCP. These questions were distilled into the following six:

- *Q.1 Do operations of the dual facilities meet the broader goal of taking advantage of wet and above average years for exports while reducing pressure on below average, dry and critically dry years? What substantive changes in operations (and responses, see below) are there both seasonally and interannually?*
- *Q.2 Based on operations criteria, does the Plan properly identify ecological impacts likely to occur adjacent to and in the bypass reach downstream of the new North Delta diversion facilities? If there will be direct and indirect harm to listed species by the facilities, does the Plan prescribe sufficient mitigation measures?*
- *Q.3 Are changes in operations and points of diversion prescribed in the Plan sufficient to significantly improve in-Delta conditions for covered species? The focus is on listed species, including delta and longfin smelt, steelhead, winter and spring run Chinook, and green sturgeon.*
- *Q.4 Are covered pelagic fish like longfin smelt and delta smelt likely to benefit from restoration of floodplain and tidal marsh habitat at the scale proposed by the Plan? Given the current state of knowledge, and assuming that all Plan commitments are met, are these efforts likely to result in relaxed X2 and spring outflow standards?*
- *Q.5 Does the Plan provide achievable, clear and measureable goals and objectives, as well as governance that is transparent and resilient to political and special interest influence?*
- *Q.6 Is there a robust science and adaptive management plan for BDCP? As described, is the proposed "decision tree" likely to resolve major issues regarding Fall X2 and Spring Outflow prior to initial operations?*

Text Box 1.1: Members of the Review Panel.

Jeffrey Mount, Ph.D. (chair), geomorphologist, Professor Emeritus UC Davis, former Chair of the Delta Independent Science Board, and Partner, Saracino & Mount, LLC

William Fleenor, Ph.D. hydrologist and water quality specialist, Research Scientist, UC Davis Center for Watershed Sciences

Brian Gray, J.D. Professor, environmental law, UC Hastings.

Bruce Herbold, Ph.D. retired US Environmental Protection Agency, former Coordinator for the Interagency Ecological Program

Wim Kimmerer, Ph.D. food web ecologist, Researcher, San Francisco State University, Tiburon Center.

Using these questions as guide, the panel reviewed selected chapters within the Plan. The focus of the review was on the biological goals and objectives for species of fish listed as threatened or endangered (BDCP Chapters 1, 2), the conservation measures proposed to meet the biological objectives (BDCP Chapter 3 and appendixes, see Text Box 1.2), and the analysis of the effects of the project on Delta fish species and communities (BDCP Chapter 5 and appendixes). The panel also examined governance, adaptive management and science programs proposed in the

Plan, including the “decision tree” intended to resolve technical disagreements about initial operations (BDCP Chapters 3, 5, 6, 7, 8, 9, 10).

In addition to reviewing BDCP documents and literature, the panel held two meetings with the consultants who prepared the Plan for the project applicants. The consultants answered questions about analyses contained within the Plan and provided or directed panel members to pertinent sources of modeling data.

Text Box 1.2: Conservation Measures Considered by the Panel

There are 22 different conservation measures in BDCP. Since the questions asked were narrowly defined, the Panel focused only on five of the measures. These include:

Conservation Measure 1: Operations and Facilities. This covers the design, implementation and operation of a new North Delta point of diversion and the operation of all SWP and CVP facilities to improve conditions for listed species.

Conservation Measure 2: Yolo Bypass Fisheries Enhancement. The Plan proposes to increase winter flooding in the Yolo Bypass to improve rearing habitat for salmon as well as improve Delta food webs.

Conservation Measure 4: Tidal Natural Communities Restoration. This measure seeks to restore 55,000 acres of tidal freshwater and brackish marsh, with an additional 10,000 acres of transitional habitat. This will improve rearing habitat for several listed species and improve food webs for pelagic fishes.

Conservation Measure 5: Seasonally Inundated Floodplain Restoration. The Plan seeks to restore 10,000 acres of seasonal floodplain outside of the Yolo Bypass. This supports juvenile salmonids and overall food web productivity of the Delta.

Conservation Measure 6: Channel Margin Enhancement. The goal of the Plan is to improve conditions for rearing salmonids along channels of the Delta with close levees. This measure will improve 20 linear miles of channel by creating mudflat, riparian and wetland habitat through levee setbacks.

Basis of Comparison

The Bay Delta Conservation Plan seeks a permit for operation of the SWP and CVP at a future date when new facilities will be constructed. As written, the preferred alternative is to construct a new point of diversion in the North Delta on the Sacramento River near Freeport, with the goal of completion in 2025. This diversion is to have three screened intakes that will divert water into forebays and a pair of tunnels capable of transmitting a maximum of 9000 cfs by gravity feed. These tunnels will link to existing SWP and CVP export facilities located in the South Delta. Permit authority for the construction and combined operations of these facilities—typically referred to as dual facilities—are the foundation of the plan. Construction and operations are paired with extensive conservation measures (see below) to mitigate for impacts of the project and to conserve and recover listed species and their biological communities.

One of the many controversies surrounding the Plan is the establishment of an environmental baseline for comparison of alternatives and analysis of the effects of the project on listed species. The requirements of the Biological Opinions (BiOps) issued by the U.S. Fish and Wildlife Service (USFWS) in 2008 and the National Marine Fisheries Service (NMFS) in 2009 constitute the baseline for the Plan. There is considerable debate between the fish agencies (NMFS and USFWS principally) and the permitees over the provisions of these BiOps, particularly in regard to requirements for high Delta outflows to support longfin smelt in the spring and high outflows to achieve Fall X2 (low salinity zone) provisions to support delta smelt. For this reason, there are two Existing Biological Conditions (EBC) considered by the Plan (Table 1.1): EBC1 includes high spring outflow provisions and EBC2, includes both high spring outflow and the new Fall X2 provisions.

A central requirement of the Plan, and the source of much of its complexity, is to analyze conditions over the 50-year life of the project. The Plan divides future conditions into two classes: Early Long Term (ELT), which captures the initial operating conditions of the project once a new diversion facility has been constructed (approximately 2025), and Late Long Term (LLT) which accounts for full completion of all conservation measures, including restoration of more than 55,000 acres of tidal marsh and floodplain (approximately 2060). Climate change, particularly changes in runoff and sea level, and changes in water demand are incorporated in these projections.

The controversy over spring and fall outflow needs for conservation and recovery of listed species propagates into the assessments of future conditions. Without-project EBC1 and EBC2 are considered for both ELT and LLT. Evaluated starting operations (ESO) of the preferred project and alternatives are presented for ELT and LLT conditions. Two additional future scenarios are evaluated that purport to provide bookends to project operations that dictate future water exports. The first is a High Outflow Scenario (HOS), which is similar to the outflow standards in EBC2 (high spring and fall outflow). The second is a Low Outflow Scenario (LOS), which has reduced outflow standards for both spring and fall. Both the LOS and HOS are considered in the ELT and LLT, with the latter including completion of habitat restoration. The Plan proposes a “decision tree process” be undertaken during construction of the facility that will reduce uncertainties and guide initial project operations, presumably within the bounds of the HOS and LOS (reviewed in Chapter 9).

For the purposes of this review, we simplified our comparison of operations and restoration scenarios to just three. Using simulation data provided by BDCP consultants we examined the HOS and LOS scenarios for ELT. We then used a no-project alternative, NAA ELT, that commonly appears throughout BDCP documentation, particularly in the EIR/EIS. NAA prescribes a high fall outflow to maintain X2 standards for smelt and D-1641 salinity and flow standards required by the State Water Resources Control Board for the remainder of the year.

Table 1.1. Definitions of existing baseline conditions and project conditions simulated in BDCP.

Conditions		**Description**
Existing Biological Conditions	EBC1	Current operations based on BiOps, excluding management of outflows to the Fall X2 provisions of USFWS 2008 BiOp.
	EBC2	Current operations based on BiOps, including management of outflows to meet USFWS Fall X2 provisions from 2008 BiOp.
Projected Future Conditions without the BDCP	EBC2_ELT	EBC2 projected into year 15 (2025) accounting for climate change expected at that time.
	EBC2_LLT	EBC2 projected into year 50 (2060) accounting for climate change expected at that time.
Projected Future Conditions with the BDCP	ESO_ELT	Evaluated starting operations in year 15 assuming new intake facility operational and restoration not fully implemented
	ESO_LLT	Evaluated starting operations in year 50 assuming new intake facility operational and restoration fully implemented.
	HOS_ELT	High-outflow operations during spring and fall in year 15 assuming new intake facility operational and restoration not fully implemented.
	HOS_LLT	High-outflow operations during spring and fall in year 50 assuming new intake facility operational and restoration fully implemented.
	LOS_ELT	Low-outflow operations during spring and fall in year 15 assuming new intake facility operational and restoration not fully implemented.
	LOS_LLT	Low-outflow operations during spring and fall in year 50 assuming new intake facility operational and restoration fully implemented.

It should be noted that the Panel chose not to review LLT scenarios and conditions beyond the question of whether restoration of marsh is likely to benefit listed fishes.

Although it is necessary and useful to consider how the project might operate over the long-term, especially under climate change, the Panel felt that exceptionally high uncertainties made it difficult to offer precise answers within the LLT framework. These uncertainties are associated with our understanding of the Delta, with the models used to simulate future conditions, and with the array of events (biological invasions, floods, droughts, earthquakes, policy changes, lawsuits, etc.) that are likely to occur.

A Note About Hydrologic Modeling Tools and Uncertainties

The basis for the BDCP analysis is hydrologic simulation modeling that provides flow, water elevations, temperature and salinity at various locations throughout the Delta and its upstream areas. Much of the Effects Analysis for aquatic species and all of the export projections are based on outputs from these hydrologic models. BDCP is one of the most complex modeling efforts of its kind and certainly the most complex ever attempted in the Delta. This is a heroic modeling effort.

There are three general categories of uncertainty in the hydrologic model results:

Model uncertainties. This includes how the model simulates hydrology and the hydrologic results of operations, including salinity, temperatures and other water quality parameters. The currently available modeling tools are less than ideal to simulate such a long-term record with dramatic changes in conditions such as sea level rise and introduced sub-tidal and inter-tidal land. The principal issues are summarized in Text Box 1.3.

Future condition uncertainties. There is extensive effort in BDCP to estimate future conditions in the Delta, including sea level rise and changes in temperature and runoff. This is the most comprehensive approach to date. These are described well in Appendix 5A of the Plan and highlight high levels of uncertainty.

Regulatory and behavioral uncertainty. BDCP models assume that flow and water quality standards will remain static during the life of the project. In addition, the models assume uniform behavior of system operators, ignoring real-time operations and adaptations. All of these are highly unlikely to occur.

The hydrologic model results of BDCP are presented as if they are a unique solution. Given the compounding uncertainties, BDCP model results should be considered as scenarios rather than specific outcomes. This issue is often lost in the public debates over BDCP. As discussed later in this report, the model uncertainties significantly impact our confidence in some of our results, particularly our analysis of the response of pelagic fishes to changes in South Delta operations.

Text Box 1.3: Hydrologic Model Uncertainty.

To adapt existing tools to model future conditions under BDCP consultants developed dispersion coefficients with the 3-dimensional UnTRIM model developed by Michael MacWilliams for sea level rise. A similar process was then followed with a 2-dimensional model developed by Research Management Associates to estimate the additional dispersion for the proposed new open tidal areas. Parameters developed from the multi-dimensional efforts were then incorporated into the 1-dimensional DSM2 planning model developed by DWR to simulate a part of the long-term record incorporating sea level rise and tidally restored acreage. The boundary conditions for the DSM2 model, which operates at time steps as short as 15 minutes, was provided by CALSIM, the 1-dimensional system-wide water operations optimization model. CALSIM output occurs on monthly time steps and had to be disaggregated to provide boundary conditions for DSM2. All the results, including the DSM2 results and artificial neural network salinity results, were then used to train the CALSIM model. The CALSIM model was then used to simulate the entire 82-year record that formed the basis for the Effects Analysis. All of these model exchanges, particularly between 1-, 2-, and 3-dimentional models, create error or model bias. To date, there is no assessment of these model biases and how they impact BDCP results.

Organization of This Report

This report is organized into nine chapters followed by a summary of answers to the guiding questions. Chapters 2-9 include:

- *Chapter 2, Overview of the Law Governing BDCP.* Although not specifically requested by TNC and AR, we found it helpful to review key provisions of the HCP/NCCP laws that set standards for recovery of populations of covered fishes.
- *Chapter 3, Water Supply Operations.* This chapter examines how BDCP performs in meeting the goal of increasing water supply reliability. This includes assessment of changes in export volumes, both seasonally and within different year types.
- *Chapter 4, Environmental Flow Performance: Upstream and Inflows.* The new facilities and their operation are supposed to improve flow conditions impacted by the SWP and CVP. This chapter describes flows regulated by project dams, flows past and through the new North Delta facilities, and the overall inflow regime of the estuary.
- *Chapter 5, In-Delta Effects on Pelagic Fishes.* The changes in flow conditions outlined in the previous chapter translate to changes in ecological conditions for listed fish species. This chapter evaluates the likely response of delta smelt and longfin smelt to these changes

- *Chapter 6, Estimated Effects of BDCP Flows on Smelt.* This chapter examines the magnitude of changes in outflow and the likely response of delta and longfin smelt.
- *Chapter 7, Likely Response of Listed Fishes to Habitat Restoration.* A fundamental hypothesis of BDCP is that restoration of physical habitat, particularly tidal marsh, will improve food web conditions for pelagic fishes, aiding their recovery. This chapter evaluates this hypothesis.
- *Chapter 8, Governance and Terms of BDCP*. The 50-year permit for the project, coupled with governance and oversight, are examined in this chapter.
- *Chapter 9, Science and Adaptive Management*. The Plan makes extensive mention of the use of adaptive management supported by robust science to address major uncertainties. The Plan's objectives in this regard are reviewed.
- *Chapter 10*, Summary and Conclusions. This chapter provides a summary of answers to the six questions presented to the panel by American Rivers and The Nature Conservancy. In addition, where appropriate, recommendations are offered for ways to improve the performance of BDCP.

Conclusion

This report is, by design, narrowly focused on a limited set of issues of concern to The Nature Conservancy and American Rivers. It is not intended to serve as a broad review of BDCP, nor is it directed toward a wide audience. In addition, the panel specifically steered away from endorsing or rejecting BDCP, and makes no recommendation on the critical question of whether American Rivers and The Nature Conservancy should support BDCP, support it with modifications, or reject/oppose it. Rather, the observations, analyses and recommendations are solely intended to inform this decision.

Chapter 2: An Overview of the Law Governing the BDCP

Introduction

This chapter provides a brief overview of the law that governs the creation and implementation of the Bay Delta Conservation Plan. It also addresses an important question that has arisen during the BDCP negotiations: May the California Department of Fish and Wildlife (CDFW) approve the BDCP as a natural community conservation plan if the BDCP does not provide for full recovery of the endangered and threatened species covered by the Plan?

Habitat Conservation Planning and Natural Community Conservation Planning Under Federal and California Law

The BDCP is a Habitat Conservation Plan (HCP) authorized by section 10(a) of the federal Endangered Species Act (ESA), 16 U.S.C. § 1539(a), and a Natural Community Conservation Plan (NCCP) authorized by the California Natural Community Conservation Planning Act (NCCPA), California Fish and Game Code §§ 2800-2835. Section 10(a) of the federal ESA allows the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) to issue permits that authorize the taking of endangered or threatened species "if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity" and the proposed activity is governed by an approved HCP. *Id.* § 1539(a)(1)(B) & (2). Similarly, under the NCCPA the California Department of Fish and Wildlife (CDFW) may "authorize by permit the taking of any covered species . . . whose conservation and management is provided for in a natural community conservation plan approved by the department." California Fish & Game Code § 2835.[1]

If approved by the three fish and wildlife agencies, the BDCP will be a legally binding document that defines the terms and conditions under which the U.S. Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR) may construct and operate the proposed new water diversion and transport facilities described in the draft Plan.[2] The BDCP also will serve as "a comprehensive

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[1] The NCCPA defines "covered species" to include species that are listed for protection under the California Endangered Species Act, California Fish & Game Code §§ 2050-2115.5, and nonlisted species that are "conserved and managed under [another] approved natural community conservation plan and that may be authorized for take." *Id.* § 2805(e).

[2] The complete statutory requirements governing the contents and approval of the BDCP as an HCP and NCCP are set forth respectively in section 10(a)(2)(A) & (B) of the federal Endangered Species Act, 16 U.S.C. § 1539(a)(2)(A) & (B), and sections 2810 and 2820 of the California Fish and Game Code.

conservation strategy for the Sacramento–San Joaquin River Delta (Delta) designed to restore and protect ecosystem health, water supply, and water quality within a stable regulatory framework" (BDCP 1-1)[3].

The BDCP will include "regulatory assurances" that protect the permittees from the financial cost of changes to the BDCP or other regulatory changes needed to protect the species or their habitat[4]. As authorized by federal and state law, these regulatory assurances provide that, if changed circumstances arise that are either unforeseen or not provided for in the Plan, then the fish and wildlife agencies will not require the permittees to devote additional land, water, or financial resources beyond the levels set forth in the BDCP without the consent of the plan participants. Nor will the federal and state regulators impose additional restrictions on project operations without compensating the permittees for the lost water or additional costs.[5]

Both statutes also authorize the fish and wildlife agencies to suspend or revoke the incidental take permits for noncompliance with the terms and conditions of the BDCP or where implementation of the Plan will place the covered species in jeopardy of extinction.[6]

We consider the regulatory assurances, revocation authority, and other aspects of BDCP governance in Chapter 8.

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[3] In addition, the BDCP will be the basis for a biological assessment that USBR will submit to the USFWS and NMFS prior to consultation under section 7 of the Endangered Species Act. BDCP 1-6. The BDCP thus will help to inform the federal fish and wildlife agencies' analysis of the new facilities and changes in coordinated CVP/SWP operations proposed in the draft Plan. The agencies then will decide whether the BDCP "is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [the species' critical habitat]." 16 U.S.C. § 1536(a)(2). If the agencies determine that the BDCP *is* likely to jeopardize a listed species or adversely affect critical habitat, the biological opinion that they issue to the Bureau will include "reasonable and prudent alternatives" designed to avoid these consequences, as well as incidental take authorization governing CVP operations. *Id.* § 1536(b)(3) & (4).

[4] The regulatory assurances will apply to all entities that are issued incidental take permits under the BDCP, including DWR and the CVP and SWP contractors if the contractors become permittees. The "no surprises" assurance will not apply, however, to the Bureau of Reclamation. BDCP 6-29.

[5] The USFWS and NMFS adopted the federal "no surprises" policy by rulemaking in 1998. The substantive requirements of these rules may be found at 50 C.F.R. § 17.22(b)(5) & (6) and 50 C.F.R. § 222.307(g), respectively. The state "no surprises" guarantees are set forth in the NCCPA itself. California Fish & Game Code § 2820(f).

[6] The federal suspension and revocation rules are set forth in the Endangered Species Act, 16 U.S.C. § 1539(a)(2)(C), and in the ESA regulations, 50 C.F.R. § 17.22(b)(8). The state law counterparts may be found in California Fish & Game Code § 2820(b)(3).

Conservation and Recovery Requirements Under Federal and State Law

The federal Endangered Species Act and the California Natural Communities Conservation Planning Act differ in their respective conservation and recovery standards. The federal statute provides that the fish and wildlife agencies may not approve the BDCP unless they determine that the incidental take authorized by the permit and HCP "will not appreciably reduce the likelihood of the survival and recovery of the species in the wild." 16 U.S.C. § 1539(a)(2)(B)(iv).

In contrast, the NCCPA states that Department of Fish and Wildlife may approve the BDCP only if it finds *inter alia* that the Plan

> provides for the protection of habitat, natural communities, and species diversity on a landscape or ecosystem level through the creation and long-term management of habitat reserves or other measures that provide equivalent *conservation* of covered species appropriate for land, aquatic, and marine habitats within the plan area.

California Fish & Game Code § 2820(a)(3) (emphasis added). The Act defines "conservation" as "the use of methods and procedures within the plan area that are necessary *to bring any covered species to the point at which the measures provided pursuant to [the California Endangered Species Act] are not necessary.*" *Id.* § 2805(d) (emphasis added).

In other words, the federal Endangered Species Act requires only that habitat conservation plans ensure that the permitted activities do no significant harm to the listed species or to their critical habitats. The California Natural Communities Conservation Planning Act, by comparison, regards proposed projects such as the BDCP as opportunities for more coordinated and cohesive planning to improve the condition of covered species and their habitat, rather than simply being a means to authorize the permitted activities while maintaining the *status quo ante.*

The draft BDCP describes its biological goals and objectives in two different ways. At the "landscape level," the goals include restoration or creation of "ecological processes and conditions that sustain and reestablish natural communities and native species" (BDCP 3.3-5). At the "species level," however, the biological goals refer to *progress toward* the landscape level goal of reestablished and sustainable natural communities and native species.

Thus, the primary biological goals for the Delta Smelt and Longfin Smelt are "increased end of year fecundity and improved survival of adult and juvenile . . . smelt to support increase abundance and long-term population viability" (BDCP 3.3-13 & 3.3-16). Similarly, the principal biological goal for Sacramento Winter-Run Chinook Salmon is "improved survival (to contribute to increased abundance) of immigrating and emigrating . . . salmon through the Plan Area," (BDCP 3.3-16), and for other species of salmon and steelhead the goal is "increased . . . abundance" (BDCP 3.3-17 to 3.3-19).

The draft BDCP explains that the process of developing these species level biological goals "did not assume that the BDCP would be solely responsible for recovery of these species, and so the designated biological goals and objectives did not necessarily match the recovery goals, but instead represented the BDCP's potential to *contribute to recovery* within the Plan Area (BDCP 3.A-14: emphasis added). This decision has become a focal point of debate over the essential purposes and mandates of the NCCPA.

In a July 10, 2013, letter to the Director of CDFW, three environmental organizations challenged the BDCP's proposed adoption of biological goals that do not provide for full recovery of the species, arguing that this "contribution to recovery" standard violates California law:

> Under the plain text of the NCCPA, conservation means recovery, and a Plan is required to contain measures that are sufficient to achieve recovery within the plan area.

The Natural Community Conservation Planning Act is the Foundation for a Successful Bay Delta Conservation Plan, Letter to Charlton H. Bonham, Director of the California Department of Fish and Wildlife, from the Defenders of Wildlife, Natural Resources Defense Council, and the Bay Institute, July 10, 2013, at 5 (citing Fish & Game Code § 2805(c)).

As described in detail in the chapters that follow, the limitations on project operations and other conservation measures set forth in the draft BDCP would not meet the conservation standard proposed by the July 10th letter—*viz.* full recovery of the listed species—though they are likely to contribute to species recovery. The letter thus raises a critical legal question that will have to be resolved by the Director of CDFW, in consultation with the Department's General Counsel and the Attorney General, before the Department decides whether to approve the BDCP.

The answer to this question is not free from doubt, as the Legislature defined the purposes of the NCCPA in terms that stand in some tension to one another. For example, section 2801(i) declares that the "purpose of natural community conservation planning is to *sustain and restore* those species and their habitat . . . that are necessary to maintain the continued viability of those biological communities impacted by human changes to the landscape." California Fish and Game Code § 2801(i) (emphasis added). In contrast, section 2801(g) states that "[n]atural community conservation planning is a mechanism that can provide an early planning framework for proposed development projects . . . in order to avoid, minimize, and compensate *for project impacts to wildlife.*" *Id.* § 2801(g) (emphasis added).

A careful and integrated reading of the text of the substantive provisions of the statute, however, should lead to the conclusion that the Act authorizes the CDFW to approve the BDCP if it concludes that the Plan would protect listed species from the adverse effects of the projects authorized by the Plan (including full mitigation of those effects) *and* would promote the recovery of listed species. Stated differently, we do not believe that the Legislature intended to prohibit the Department from approving the BDCP unless it concludes that the Plan—in isolation both from other existing sources of the species' decline and from other state and federal actions to protect listed species—will achieve full recovery of the species. We reach this conclusion for several reasons.

First, the interpretation of the statute proposed in the July 10th letter is based entirely on the section of the Act that defines the term "conservation." If the Legislature actually intended to require the CDFW to determine that an NCCP would be likely to achieve full recovery of listed species, it would have included this requirement in Section 2820, which governs the Department's approval of proposed NCCPs.

Section 2820(a) lists ten separate findings that are prerequisite to CDFW approval, and section 2820(b) contains nine terms that must be included in the implementation agreements that accompany the NCCPs. None of these mandatory findings and terms includes the requirement proposed in the July 10th letter. We do not believe that the Legislature somehow intended to add a twentieth requirement to these lists—that the NCCP and implementation plan must provide for full species recovery—by implication from the definitions section of the Act.

Second, there are two provisions in section 2820 that expressly link the required conservation measures to the effects of the project authorized by an NCCP. Section 2820(a) states that the CDFW may approve an NCCP only if it finds that the plan

> contains *specific conservation measures that meet the biological needs of covered species and that are based upon* the best available scientific information regarding the status of covered species and *the impacts of permitted activities on those species*. [*Id.* § 2820(a)(6) (emphasis added).]

Section 2820(b) stipulates that implementation agreements must include provisions

> to ensure that *implementation of* mitigation and *conservation measures on a plan basis is roughly proportional in time and extent to the impact on habitat or covered species authorized under the plan*. These provisions shall identify the *conservation measures* . . . that will be maintained or carried out in *rough proportion to the impact on habitat or covered species.* [*Id.* § 2820(b)(9) emphasis added).]

This pairing of conservation and recovery with references to the "impacts of permitted activities," together with the "rough proportionality" limitation on conservation measures, suggests that the Legislature intended to authorize NCCPs as a means of contributing to other state and federal efforts to recover species, but not significantly in excess of the burdens that the project covered by the plan would impose on the species.[7]

Third, there is nothing in the text or legislative history of the NCCPA to indicate that the Legislature intended to force the state to bear programmatic and financial responsibility for full species recovery each time the CDFW approves an NCCP.[8] Conservation measures required to achieve full recovery may extend far beyond the scope of an individual NCCP. Indeed, a requirement of full recovery would be particularly problematic for plans such as the BDCP that involve multiple species (some of which only partly inhabit the program area), multiple sources of stress, and diverse land and water management and regulatory agencies that each have independent obligations to contribute to species conservation and recovery. We do not believe that the Legislature would have assigned such a Herculean obligation to the Department, or imposed such a potentially large financial burden on state taxpayers, without saying so explicitly in the text of the statute.

Finally, an interpretation of the statute that would require the CDFW to make a determination that all proposed NCCPs provide for full recovery of listed species would likely have the unintended and pernicious consequence of deterring the Department from approving future plans. The CDFW might conclude that the scope of the necessary species recovery effort extends beyond the scope of the proposed project and hence beyond the capabilities of the project restrictions and conservation measures that would be included in the individual NCCP. Or it might be reluctant to approve an NCCP in situations where the costs of full recovery of the listed species covered by the plan—which the state would have to bear—significantly exceed the project mitigation costs that may be placed on the project proponents.

Again, these factors are especially pronounced in contexts such as the Delta ecosystem where there are multiple species (some of whose habitat is only partly

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[7] The July 10th letter acknowledges that the NCCPA contains this "rough proportionality" limitation, but argues that "the concept of 'rough proportionality' is applied only to mitigation measures and not to a plan's conservation measures." Letter to Director Bonham at 7. The text of the Act belies this interpretation, however, as four of the five statutory references expressly apply the "rough proportionality" limitation to the conservation requirements. *See* California Fish & Game Code §§ 2805(g)(3)(C), 2820(b)(3)(B), § 2820(b)(9) & § 2820(c).

[8] The July 10th letter recognizes that the entities that receive incidental take permits under the BDCP may not be required to bear all of the costs of recovery of the various listed species: "[W]hen dividing up the costs of the plan's conservation strategy, the individual developers are only responsible for paying for 'mitigation' and the 'conservation' increment above mitigation is the responsibility of the state." Letter to Director Bonham at 7. Thus, if the costs of recovery exceed the mitigation costs that lawfully may be assigned to the permitted entities, the state must make up the difference: "The BDCP cannot limit its conservation measures to address only those impacts from the covered activities and avoid providing conservation measures sufficient to recover covered species." *Id.* at 8.

within the project area), multiple stressors (many of which are not plan participants), overlapping and sometimes conflicting habitat requirements, and tremendous uncertainty both about the needs of the species and the likelihood of success of recovery strategies. The interpretation of the NCCPA set forth in the July 10th letter therefore poses a significant policy risk of deterring otherwise salutary applications of natural resources conservation planning.

Conclusion

We conclude that the draft BDCP's establishment of biological goals and conservation measures that are based on the Plan's "potential to contribute to recovery" of the covered species complies with the Natural Communities Conservation Planning Act. We also believe that the CDFW may approve the Plan if it determines that the BDCP will ensure the survival of the listed species, fully mitigate the adverse effects of the project on all covered species and their habitat, and further the more general state and federal efforts to recover the species and to restore the favorable conditions of their habitat.

Chapter 3: Water Supply Operations

Introduction

The construction of a new North Delta diversion facility, and the coordinated operation of the North and South Delta facilities constitute the first and most prominent conservation measure (CM#1) of the BDCP. While ostensibly a conservation measure, the new facilities are principally an effort to improve the reliability of exports from the Delta. Their operations, in conjunction with all other conservation measures, are intended to mitigate for impacts of the CVP and SWP, avoid jeopardy and/or to contribute to the recovery of covered species (Chapter 2).

A basic premise of BDCP is that the construction of the new North Delta diversion facility will simultaneously improve water supply reliability while reducing ecosystem impacts. This stems from the increased operational flexibility associated with two points of diversion located in different portions of the Delta. A presumed benefit of this flexibility is the capacity to take advantage of periods of high inflow for exports, allowing for reductions in exports during dry periods when impacts on the ecosystem may be largest. This is consistent with the co-equal goals expressed in the 2009 Delta Reform Act.

This chapter examines the water supply operations proposed under BDCP to evaluate 1) if there are significant changes in supply reliability associated with the project and 2) how these changes apportion exports in wet vs. dry periods. This description is foundational for the assessment of ecological and species-specific consequences of BDCP as described in subsequent chapters.

Proposed Facilities and Operations

There are lengthy descriptions of the design and operation of new and existing water export facilities in the Administrative Drafts of the EIR/EIS and BDCP. The reader is referred to these documents for information. The centerpiece of the plan is the 9000 cfs capacity diversion in the North Delta that conveys water to the SWP and CVP export facilities in the South Delta through two tunnels.

Regulatory Constraints

The operational criteria for the export facilities are both complex and highly constrained (Appendix A). As outlined below, these constraints *significantly reduce the operational flexibility of the facilities*. The current regulatory constraints include but are not limited to:

- SWRCB water rights decision D-1641: this includes standards for minimum monthly Delta outflow, salinity objectives at multiple Delta locations, location of X2 (the position of the 2 ppt salinity near the channel bottom), a maximum export/import ratio objective[1], closures of the Delta Cross Channel (DCC), placement of a barrier at the head of Old River, and flow standards for the San Joaquin River below Vernalis. These standards vary depending upon months of the year and water year type.

- Remanded 2008 USFWS Biological Opinion (BiOp): prescribes restrictions for magnitude and timing of reverse flows in Old and Middle River (OMR) in the South Delta, to protect delta smelt. These vary depending upon time of year, water temperature, flows on the San Joaquin River, and proximity of smelt. This BiOp also calls for higher spring and fall outflows that exceed D-1641 standards. These outflow standards vary on water year type.
- Remanded 2009 NMFS BiOp: has different restrictions on OMR flows than the USFWS BiOp. Reductions in reverse OMR flows are scheduled to protect outmigrating salmonids. These vary depending on temperature and inflow. This BiOp increased San Joaquin River flows and set export/San Joaquin River flow ratios that are more restrictive than D-1641.

There are other regulatory constraints beyond D-1641 and the two remanded BiOps; however, compliance with these regulations appears to dominate water supply export modeling. Additional constraints are based on proposed operating rules for both the North and South Delta facilities. The most significant include:

- Maintenance of minimum flows downstream of the North Delta facility (called "Bypass Flows")
- Restrictions aimed to reduce reverse flows at the confluence between the Sacramento River and Georgiana Slough
- A tiered, three-level pumping regime for December through June that seeks to protect the initial winter flood pulse and spring pulses that affect juvenile salmon outmigration
- Flows with sufficient velocity to reduce impingement of salmonids at diversion screens
- Increased restrictions for reverse Old and Middle River (OMR) flows associated with South Delta exports.

Infrastructure and Inflow Constraints

Infrastructure design and capacity forms another array of constraints. For the purposes of BDCP simulation modeling, south of Delta storage was limited to space within San Luis Reservoir. Operations during wet and above average conditions are often constrained by available space to store water in this facility. Expanding potential storage, particularly groundwater storage, would have created considerably more flexibility in exports, particularly during wet years.

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[1] BDCP treats the export/import ratio in two ways: 1) counting as "import" all inflows from the San Joaquin and Sacramento Rivers and Delta's tributaries or 2) counting inflows as above, but counting flows below the North Delta facility as inflow. The latter approach seeks to exclude North Delta exports from D-1641 export/import restrictions. From an ecosystem perspective, this makes no sense since the North Delta exports are, in effect, exports from the legal Delta.

The size of the North Delta facility is also a constraint, principally during periods of sustained high flow on the Sacramento River in wet years. The preferred project has shifted from an initial facility size of 15,000 cfs to 9,000 cfs in the current plan. The export, economic and environmental performance of the 9,000 cfs facility is compared to 14 alternatives in Chapter 3 and 5 of the Draft EIS/EIR. These alternatives vary facility size, location and operations in the comparison. A narrative is presented in the EIS/EIR that describes the rationale for rejecting the 14 alternatives and selecting the preferred project[2].

Exports are also naturally constrained by the timing and volume of inflows, with strong seasonal and interannual variation. One of the larger export challenges faced by BDCP is its location at the bottom of the system where flows enter the Delta. Upstream water management and consumptive use dominate inflows to the Delta over most years (Figure 3.1). These abstractions, which consume roughly ¼ of water that would naturally flow to the Delta, are beyond the control of BDCP, yet are the greatest operational influence on Delta inflows. Under BDCP, exports would be roughly equivalent to upstream consumptive use.

In addition, there are important restrictions on reservoir operations that constrain exports. The USACE has congressionally authorized rule curves that dictate Fall, Winter and Spring operations to maintain flood reserves. More importantly, there are BiOps that dictate flow and temperature requirements to meet the life history needs of covered salmon, steelhead and sturgeon below the dams. Meeting these standards, particularly in drier years and under a warming climate, limits the amount and timing of inflows to the Delta. Oroville Reservoir, which has fewer restrictions on flows, becomes the most important for supporting Delta inflows as a result, particularly during drought conditions (see below).

Consequences of Constraints

The above discussion is intended to highlight a conundrum that is not discussed much outside of the BDCP community of experts and is not examined in the Plan: export operations and operations to support conservation are *highly* constrained. These regulatory, operational and infrastructure constraints limit the ability of BDCP to adaptively manage operations to support co-equal export *and* ecosystem objectives. For this reason, the anticipated management associated with the new diversion facility is not fully realized.

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[2] It is beyond the scope of this review to examine facility size in detail. In general, the analyses offered in the EIR/EIS conclude that the 9000 cfs facility provides the optimal balance of cost and flexibility. The additional capacity of the 15,000 cfs facility is rarely used in the operations that they modeled, leading to a very modest increase (<250 taf) in overall exports. The EIS/EIR did examine smaller facilities with capacities of 6000 and 3000 cfs. However, the operating criteria used to evaluate these two alternatives are not comparable to those of the preferred alternative, making the comparison moot.

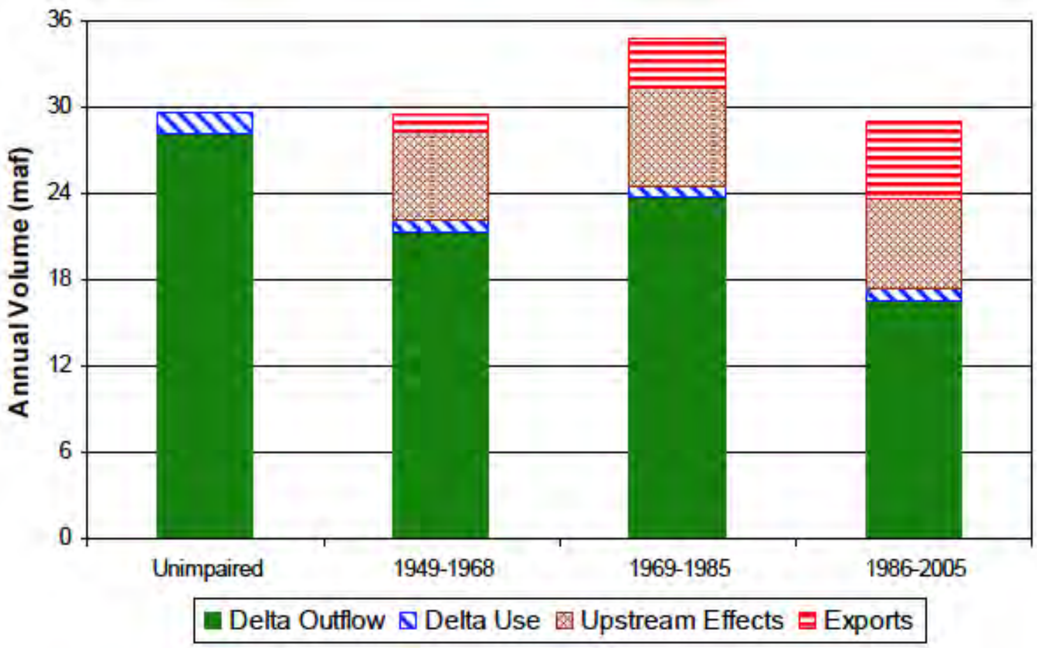

Figure 3.1 Proportional Delta water use. Exports constitute roughly 18% of the total unimpaired flow of the Delta in the 1986-2005 hydrology, with upstream consumptive use approximately 24%. From Fleenor et al. (2010).

This also highlights how flow management in BDCP was developed using system models. As described in Appendix 5C of the Plan, the models sought to meet the requirements of D-1641, the remanded BiOps, reservoir and diversion facility constraints, and south of Delta storage. The objective function was then to maximize Delta exports within those constraints. Although this seems logical, it highlights how CM1 is not a conservation measure, per se. Rather than doing a bottom-up assessment of ecosystem flow needs, as is typically done when setting environmental flows, the modeling sought to meet current regulatory requirements and flow constraints sought by fish agencies. This illustrates one of the key points made by Lund et al. (2010) and Moyle et al. (2012) that multi-objective management of the Delta is likely to require a comprehensive re-evaluation of flow and water quality standards.

Export Reliability

A goal of the BDCP project and the current Delta Plan is to improve reliability of water derived from the Delta for consumptive uses[3]. Using model simulations provided by BDCP consultants, we have evaluated how well BDCP meets the goal of improving export reliability. The most commonly discussed aspect of BDCP—

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[3] In actuality, the most reliable system would provide a given amount of water each year with the smallest deviation from that amount. Instead, BDCP attempts to produce the most water in any given year under the given regulatory and operational constraints. This produces a more *resilient* water supply systems, whereby the greatest volume is made available, even under the event of catastrophic salinity intrusion into the Delta. The terms resilient and reliable are used interchangeably in BDCP and other documents.

average annual export—is summarized in Figure 3.2, and compares the no-project alternative, NAA with the high outflow scenario, HOS and low outflow scenario, LOS (defined in Chapter 1). This modeling suggests that the HOS and NAA would provide roughly equal average exports, with the LOS providing approximately 700 taf more. However, these figures are an average over an 82-year simulation period and offer little information about reliability.

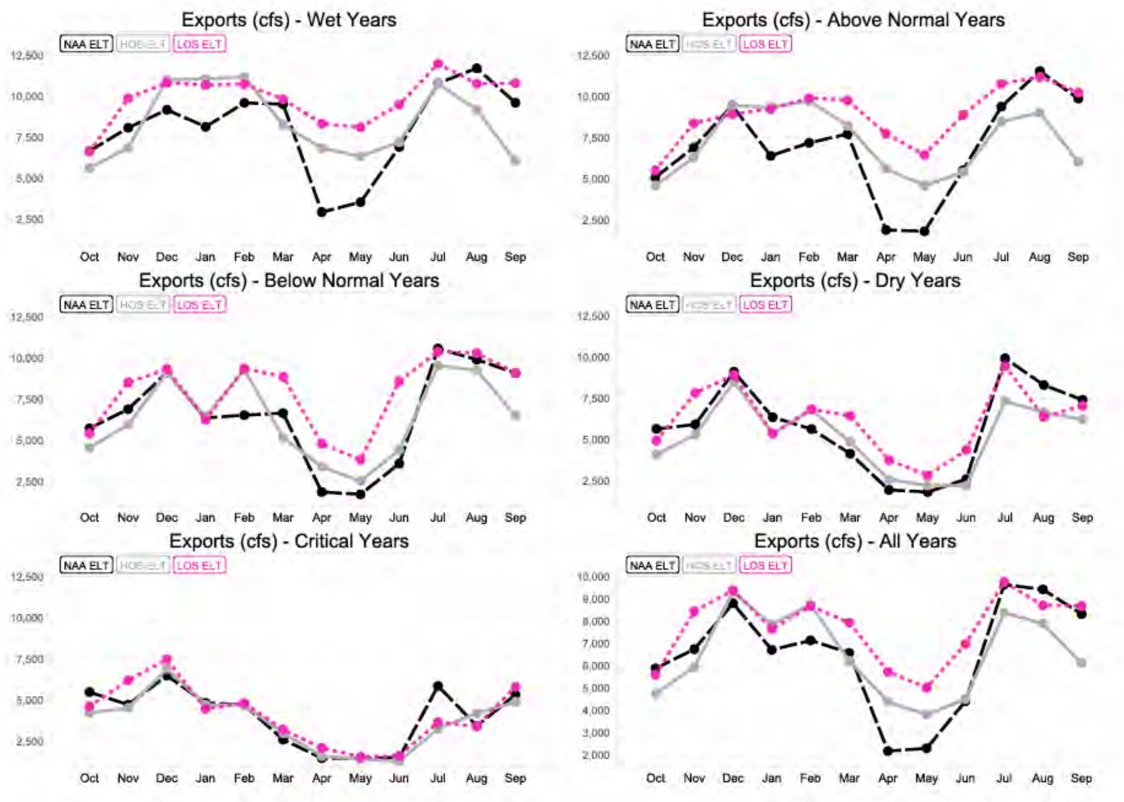

Figure 3.2: Monthly averaged exports for NAA, LOS and HOS under ELT conditions. Based on BDCP CALSIM data.

Exceedance curves (Figure 3.3) give a better indication of reliability. This approach provides the probability that a given export volume will be equaled or exceeded in any given year. For example, for the 50% exceedance probability (meaning one out of every two years), the NAA performs slightly better than the HOS, but much worse than the LOS. Overall, the LOS performs significantly better than NAA in six out of ten years and better than the HOS in eight out of ten. The HOS is outperformed by the NAA in five out of ten years (drier) and appears to only provide significant water supply benefits over the NAA in one out of ten years (wettest). The conclusion is that export reliability for the HOS and NAA are not substantially different, while reliability for the LOS is markedly higher.

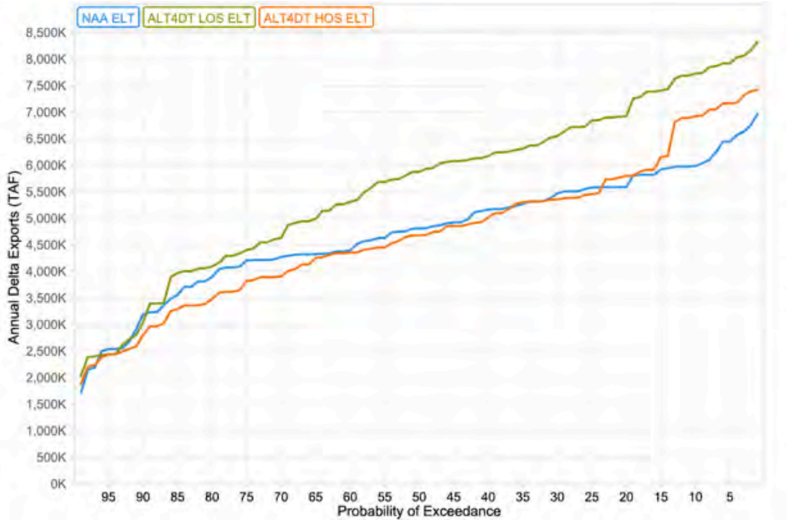

Figure 3.3: Exceedance probabilities for NAA, LOS and HOS exports under ELT conditions. Note that LOS produces higher exports for all probabilities, suggesting that it is the most reliable/resilient of the scenarios.

Water supply reliability curves for SWP and CVP customers are presented in Chapter 5 of the Draft EIS/EIR. These curves indicate that south-of-Delta municipal and farm users would realize considerable increases in overall reliability of supply under the LOS, compared to the NAA and HOS, particularly in above average and wet years. North-of-Delta users of CVP water would likely see a decrease in reliability over the long term, principally due to climate change.

Export Timing

A goal of BDCP and the Delta Plan is to shift exports to wetter years and to reduce pressure on drier years. A comparison of the average exports of NAA, LOS and HOS for all five year-types is presented in Figure 3.2. Based on the modeling data provided, there appears to be a significant increase in LOS exports in above average and wet years as compared to the NAA, with HOS intermediate between the two. This increase is accomplished through increased use of the North Delta facility during winter and spring periods when OMR restrictions most strongly impact South Delta operations.

Below average, dry and critical dry year performance of BDCP is mixed (Figure 3.2). For LOS, overall exports during the drier years are higher than the NAA, while HOS exports are roughly the same as NAA. Exports, on average, for both the LOS and HOS tend to be higher than the NAA in the winter and early spring, and lower during the summer. This minimal change in exports during dry years stems, in comparison to wet years, from the constraints on North Delta facility operations. As is illustrated below, during dry periods the North Delta facility is used very little, creating pressure on South Delta facilities.

In sum, although there are many regulatory and infrastructure constraints, BDCP does make use of the dual points of diversion to create modest increases in wet year exports and, depending on which export scenario is evaluated, equal to or greater exports in drier years. *BDCP therefore does not achieve the broader goal of reducing pressure on the Delta during dry years by shifting exports to wet years*.

Drought Performance

In the draft Plan and EIR/EIS, export performance of BDCP is summarized by presenting averages, typically linked to water year-types based on the Sacramento 40-30-30 index. Averaging fails to fully reflect how the system might be operated, however, because the complex rules governing operation can create significant year-to-year variability in exports (although see concerns over model uncertainties described in Chapter 1). This issue is particularly acute during multi-year droughts, when carryover storage in reservoirs is greatly reduced and demand increases significantly. To better illustrate how this system might perform we examined time series of model outputs during drought periods.

There were two six-year droughts during the 20th Century that fall within the time period used for hydrologic simulations: water years 1929-34 and 1987-92. We focused on the 1987-92 period of record for evaluation because it has historical export data for comparison and facilities that are comparable to today. As shown in Figure 3.4, overall export timing and magnitude during the six-year drought were roughly the same for the NAA, LOS and HOS, with LOS performing marginally better for exports throughout the drought[4]. The significant exception to this pattern is in the one year in that sequence, 1989, where modest inflows to the Delta occurred in the winter. Once bypass flow criteria were met, the flexibility created by the North Delta facility was able to take advantage of these inflows during a period of high restrictions on South Delta pumping to protect smelt.

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[4] Figure 3.4 highlights one of the issues not discussed in BDCP documentation. The environmental baseline for the BDCP assessment was determined to be the remanded BiOps, with provisions of one of the BiOps (high fall X2 flows in above normal and wet years) yet to be enacted. By choosing this as a baseline, the plan does not provide a comparison with how the project was actually operated under historic conditions. This administrative decision to only compare proposed operations with the remanded BiOps masks the striking differences between historic export operations and those proposed under BDCP.

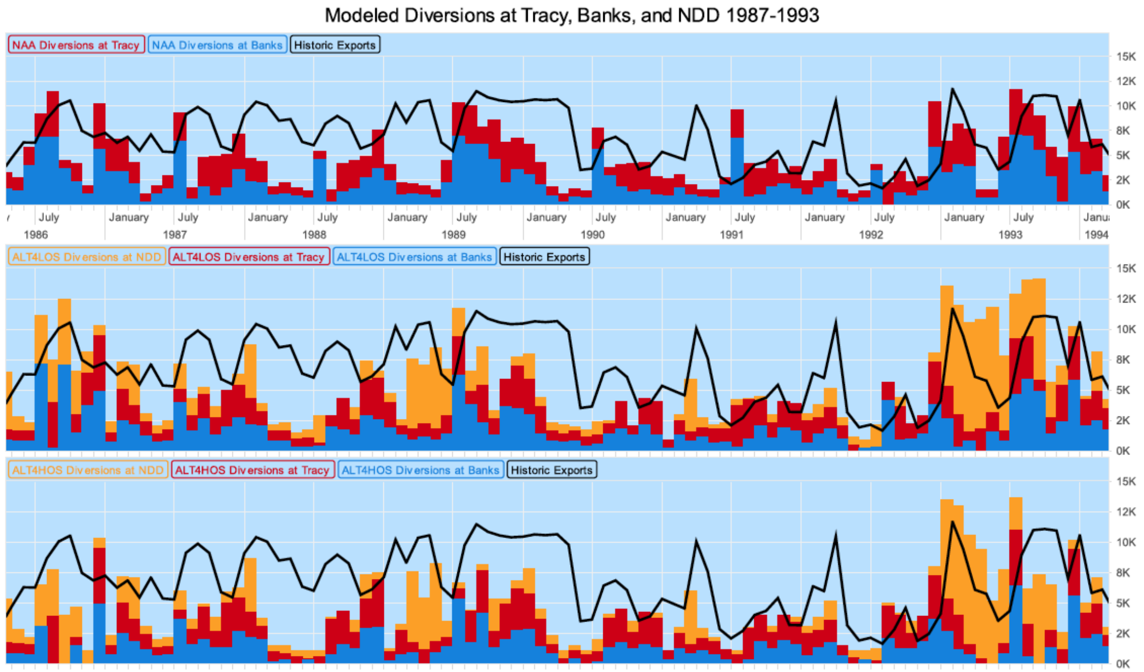

Figure 3.4: Exports for NAA, LOS and HOS under ELT conditions simulated for the 1987-92 drought, with historical exports are plotted for comparison. Important to note that ELT conditions take into account minor changes in climate and sea level rise by 2025 and cannot be compared specifically with historic conditions. In addition, historic conditions reflect human behavior; simulated conditions are guided by algorithms that do not account for human behavior.

Role of Reservoirs in Drought Management

Reservoir storage and operations play a critical role in drought management in California and greatly influence the timing and magnitude of Delta exports. The CALSIM modeling conducted for BDCP manages reservoirs within operational constraints described above and in detail in Chapter 3 of the Plan. The Plan makes it clear that the plan area does not include these reservoirs. Existing and future BiOps will govern their operations, not the terms of the HCP/NCCP permit. Despite this, the plan does envision significant changes to the operations of Oroville Reservoir under BDCP.

The 1987-92 simulated operations of the three most important reservoirs—Shasta, Oroville and Folsom—are shown in Figure 3.5. These simulations have important biological implications that are covered in later chapters. For water supply reliability, there are several important observations:

- As noted by the BDCP documentation, the NAA puts a great deal of pressure on upstream reservoirs to meet flow requirements, with Oroville providing most of the operational flexibility. In comparison to historic operations, the NAA significantly reduces storage, and thus carryover, in Shasta and

Oroville, but has limited impact on Folsom, with the exception of the last two years of drought.

- Under NAA all three reservoirs are at or near dead pool for the last two years of the drought cycle. Had water-year 1989 been closer in runoff to the other drought years, dead pool conditions would have occurred for the last three years of the six-year drought. Although a statement of the obvious, dead pool limits flexibility in managing water supply and ecosystem needs, both immediately downstream and in the Delta. This is likely to be of greatest concern for managing flow and temperature needs of winter- and spring-run Chinook salmon, particularly under warming climate conditions. Changes in flow releases to meet the needs of listed salmon are highly likely to impact export operations during dry periods. BDCP recognizes this as a concern but does not analyze the likely effects.
- A surprising result of the simulations is that HOS drought operating procedures are more protective of reservoir storage than either NAA or LOS. In an extended drought, storage is more aggressively allocated to either outflow (NAA) or exports (LOS), with both increasing the risk of creating dead pool conditions. This suggests that HOS operating criteria designed to protect smelt, may also do a better job of protecting upstream conditions for salmonids and sturgeon by increasing carryover storage. This, in turn may inadvertently improve water supply resiliency during drought.

It is important to note that a time series analysis of one extended drought within a single simulation record does not give guidance on how the system is likely to perform in all future droughts. Each drought is different, with different storage (reservoir and groundwater) conditions at the start, different precipitation and temperature patterns, and different regulatory or operational responses. To test the above observations more thoroughly, a range of six-year drought scenarios, should be simulated and analyzed. Given that most climate models prescribe an increase in frequency and duration of drought, this anecdotal assessment highlights an issue that is likely to occur during the life of the project and have significant impacts on supply as well as ecosystem management.

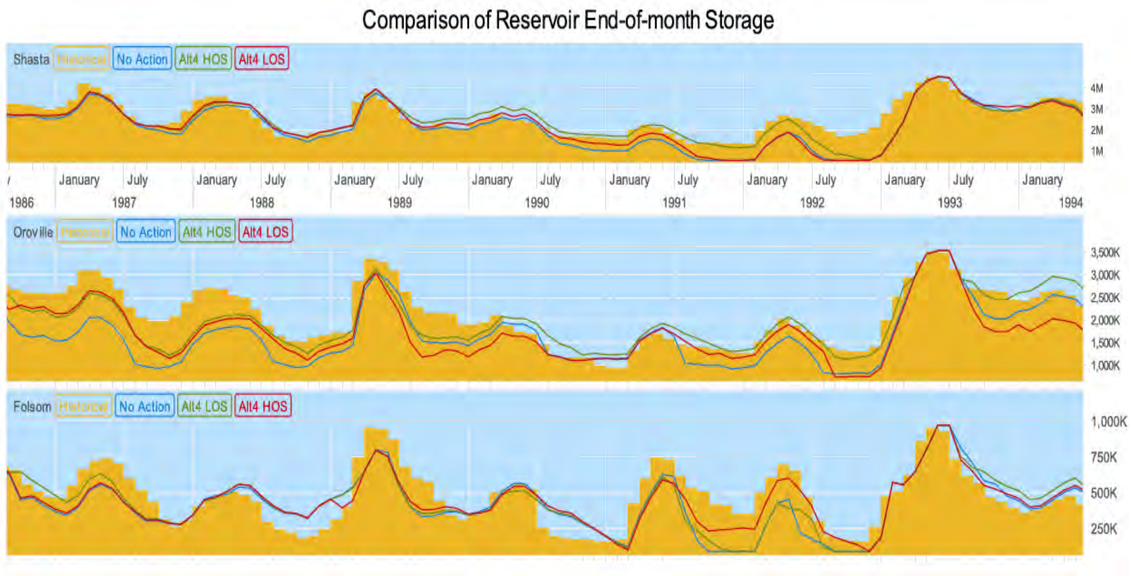

Figure 3.5: End of month storage for HOS, LOS and NAA under ELT conditions simulated for the 1987-92 drought. Historical storage (yellow histogram bars)is plotted for comparison. During the latter stages of the drought, dead pool conditions occur on all three reservoirs. Note that ELT conditions take into account minor changes in climate and sea level rise by 2025 and cannot be compared directly with historical conditions.

Conclusions

The project described in the Draft BDCP and the accompanying Draft EIR/EIR seeks to improve water supply reliability for water exported from the Delta while improving conditions for covered species. An underlying premise for the effort is that adding a second point of diversion, the North Delta facility, operated in conjunction with existing South Delta facilities will allow for more flexible export operations that better support environmental goals and objectives. In concept, this approach appears reasonable and should provide significant flexibility. In practice, however, regulatory and infrastructure constraints, coupled with high upstream consumptive uses of water, severely limits flexibility in operations. These highly constrained operations limit the effectiveness of BDCP in improving water supply reliability.

One of the objectives of BDCP that is in line with those of the Delta Plan is to increase exports during wet periods and decrease them during dry periods when impacts on the ecosystem are greatest. In comparison to the no project alternative, the new facility appears to achieve the former to a modest degree, but it does not significantly reduce pressure on the Delta during drier periods.

The proposed system is particularly vulnerable to extended drought periods (3-6 years). The NAA and LOS lead to dead pool conditions in upstream reservoirs after 3-4 years of drought. This decreases water supply reliability during dry periods and, as discussed in later chapters, places at risk species dependent upon reservoir releases, particularly cold water pool releases. This problem is likely to be particularly acute as climate changes. The surprising result from the model outputs is that the high outflow scenario, principally designed to improve conditions for smelt in the Delta, leads to improved carryover in upstream reservoirs that, in turn, improves year to year water supply reliability and allows for greater flexibility to manage reservoir-dependent species.

The hydrologic modeling effort for BDCP is unprecedented and heroic. However, the tools available for this modeling do not match the information demands. In addition, the plan documents do not do an adequate job of quantifying model uncertainties, particularly those caused by exchanges between 1-, 2- and 3-dimensional models, uncertainties over future conditions, and regulatory behavioral uncertainties . New tools will be needed going forward.

Chapter 4: Environmental Flow Performance: Upstream and Inflows

Introduction

The focus of the BDCP is principally on the legal Delta and adjacent Suisun Bay and Marsh, where export operations have the most direct impact on covered species. As discussed in Chapter 3, upstream management, including reservoir operations, consumptive uses of water, and flood management, play a critical role in inflow timing and volume. In this chapter, we examine how conservation measures #1 (water operations) and #2 (Yolo Bypass fisheries) meet conservation objectives that impact listed aquatic species.

The focus of this chapter is on the environmental performance of proposed flow changes in the Sacramento watershed, including the Sacramento, Feather and American Rivers, and inflows to the Delta through the Yolo Bypass and the Sacramento River. Although inflow from the San Joaquin River is important and a determinant of conditions in the South Delta, BDCP does not envision significant changes in flows. For this reason, our analysis is focused only on the Sacramento watershed.

Performance, as used here, is how well actions proposed by BDCP are likely to meet the goals and objectives of the plan. Although there are many issues discussed in the Plan for the Sacramento system and covered species, there are three central flow performance concerns: changes in reservoir release timing and magnitude and its impact on anadromous fishes; modifications to Fremont Weir and its benefits for floodplain habitat for outmigrating salmonids; and near- and far-field effects of North Delta diversion operations.

Impaired Flow in an Impaired System

One of the objectives of BDCP and the Delta Plan—and a concern of many NGOs--is to produce a flow regime with attributes that better support the life history stages of covered aquatic and riparian species. This objective is supported by a large body of national and international literature that has demonstrated how creating more natural flow regimes in highly regulated systems improves conditions for native species (see recent summary by Arthington, 2012). This issue has been at the forefront of controversial efforts by the SWRCB to develop a basin plan that addresses flows (Fleenor et al., 2010).

A flow regime that mimics natural seasonal variation is also considered by the scientific community in the Delta to be fundamental to better species management (Hanak et al., 2013). Restoring appropriate seasonal and intra-annual variability involves re-establishing flow timing, magnitude, duration, frequency and rates of change that drive key ecosystem attributes that, in turn, support native species (Figure 4.1).

Although restoring elements of the natural flow regime is a worthwhile goal, it should be made clear that in the Delta and its tributaries there is little that remains natural (Bay Institute, 1998; Whipple et al., 2012). Added to these physical changes are profound shifts in biological conditions, including a Delta ecosystem dominated by non-native plants and animals (Lund et al., 2008; Baxter et al., 2010). For this reason, restoring a more naturally variable flow regime in an altered Delta and its watershed, while necessary for improving conditions for covered species, is unlikely to lead, by itself, to their recovery (Mount et al., 2012).

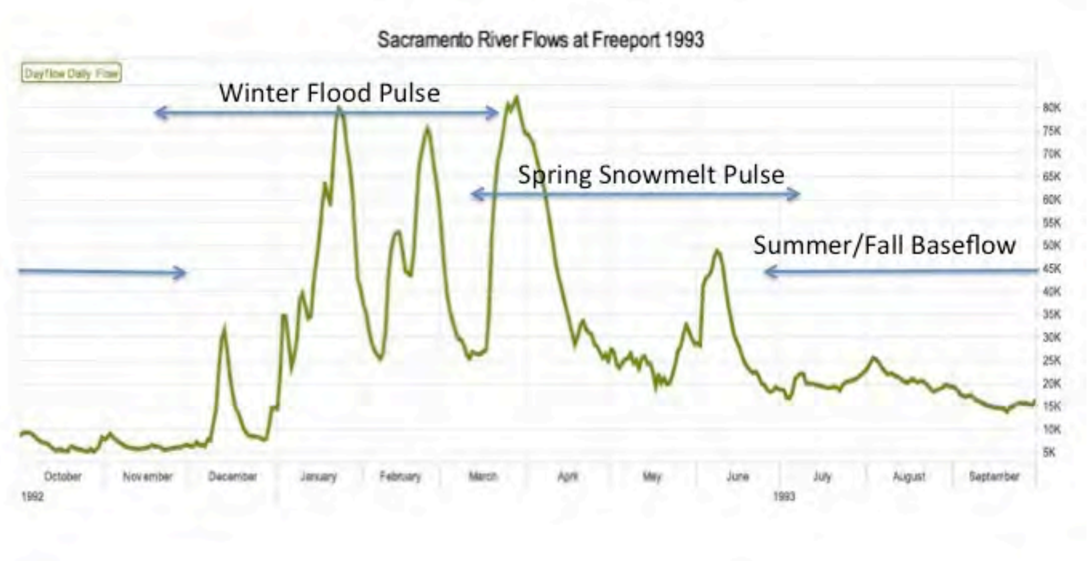

Figure 4.1: Unimpaired Sacramento River flow at Freeport for WY 1992-3 based on DAYFLOW data (DWR). This illustrates the range of natural seasonal variability in flow. Reproduction or migration of aquatic and riparian species are tied to timing, magnitude, frequency, duration and rate of change of flows. Flows, particularly winter and spring flood pulses, are necessary for geomorphic processes that support various life history stages. Flow regulation and land reclamation have significantly altered flow regime (see text for discussion).

In this chapter we sought to evaluate BDCP's potential impact on flow regimes upstream and into the Delta. It is infeasible—if not inappropriate--to reconstruct natural flow in the Central Valley given the significant changes in the landscape. Instead, we use *unimpaired flow* (DWR 2007) as a proxy for a more naturally distributed flow regime[1]. Unimpaired flow is the volume of water that would flow by a given point if no upstream impoundments or diversions were in place. Estimating

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[1] We focus here principally on the rivers that feed into the Delta rather than the Delta per se. An assessment of changes in outflow that occurs in response to changes in operations is contained in Appendix B.

unimpaired flow is complicated and imprecise, yet is important in setting flow and water quality targets, particularly by the SWRCB. It involves aggregating unimpaired and unregulated runoff from multiple basins that flow to the Delta. Unimpaired flow ignores surface water-groundwater interactions and storage or conveyance of flow in channels, floodplains and wetlands. For this reason, it is not a useful proxy for flow regime on daily time steps, but can be used as an imperfect proxy for annual and monthly flows. We follow that convention in this analysis.

This simplified approach should not be over-interpreted. It is used to assess whether BDCP meets the overall goal of improving ecological conditions by creating a more natural seasonally variable flow regime. It does not address all issues of concern for listed fishes, such as winter- and spring-run Chinook salmon whose primary limitation is due to loss of upstream spawning and rearing habitat and high temperatures in existing channel habitat (Williams, 2006, 2009).

Main Rivers of the Sacramento Valley

Multiple biological goals and objectives of BDCP are associated with flow conditions on the Sacramento River and its two main tributaries, the Feather and American Rivers. All anadromous fishes covered by BDCP rely directly on these river systems for spawning, rearing and migration. As noted in Chapter 1, we focus here principally on winter- and spring-run Chinook since the BiOps that cover their life history needs have the greatest impact on water operations.

With the exception of proposed changes to the Fremont Weir and the Yolo Bypass (CM#2), BDCP does not envision making significant investments in improving physical habitat upstream of the Delta, or addressing other stressors such as hatcheries, contaminants or harvest procedures (see summary in Williams, 2006, 2009). For this reason, most of the impact of BDCP on the Sacramento River and its tributaries upstream of the North Delta facilities will be associated with changes in flow releases from the three major reservoirs: Shasta, Oroville and Folsom.

Simulated average flow conditions affected by changes in reservoir operations under BDCP are summarized in Figure 4.2A-C, including Sacramento River at Red Bluff, Feather River below Oroville Reservoir, and American River below Folsom. These flows, along with all other tributaries, aggregate to form the Freeport flow (Figure 4.2D) and the Yolo Bypass. These results include NAA, LOS and HOS flow scenarios and unimpaired flow under the five year-types based on the Sacramento River wetness index.

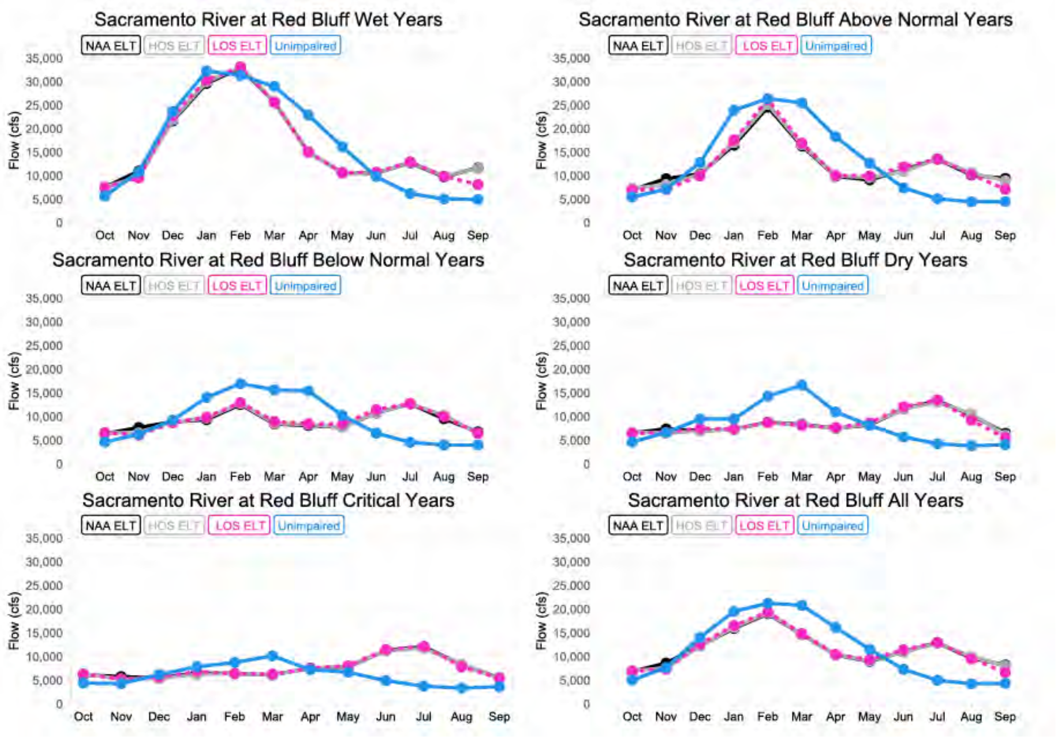

Figure 4.2A: Sacramento River at Red Bluff.

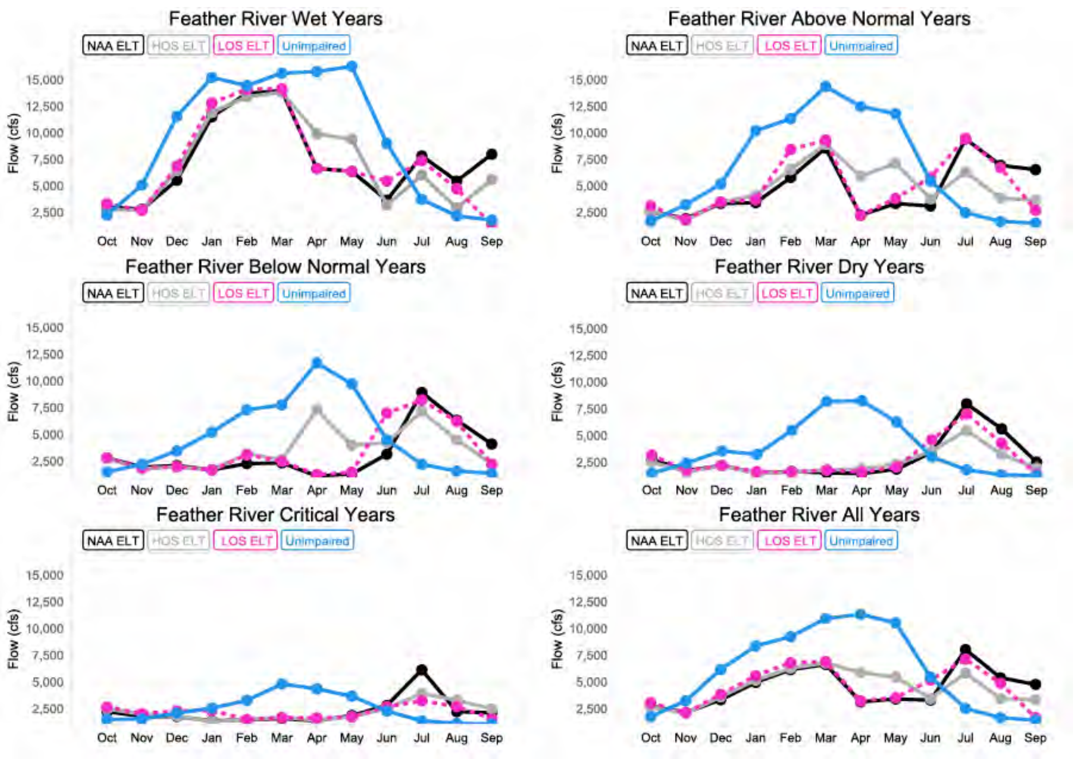

Figure 4.2B: Feather River.

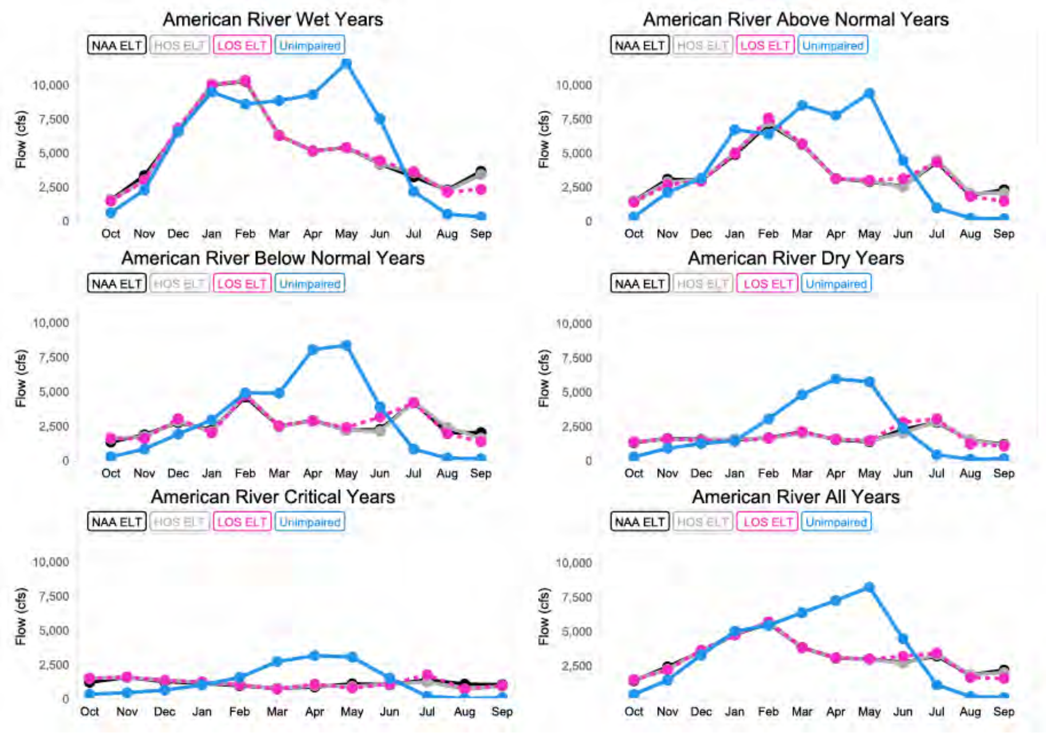

Figure 4.2C: American River.

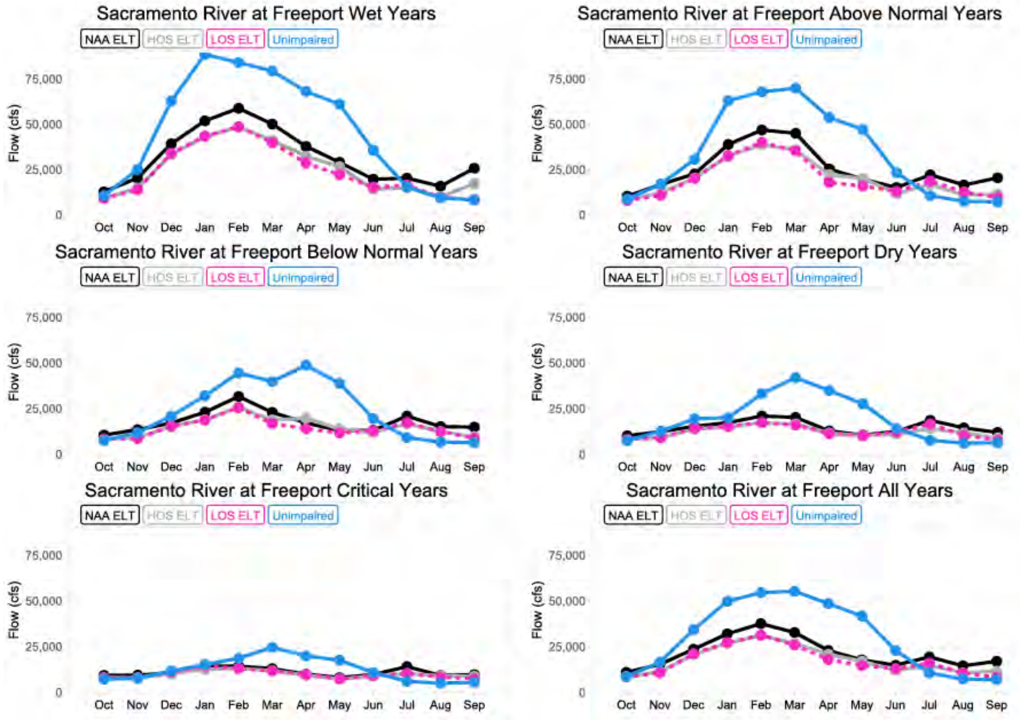

Figure 4.2D: Flow at Freeport. Figures 4.2A-D. Monthly averages sorted by water year types for HOS, LOS, NAA and unimpaired flow. Unimpaired flow is based on current conditions and HOS, LOS and NAA are ELT conditions. See text for discussion. Data from BDCP CALSIM simulations.

As noted in Chapter 3, the constraints on reservoir operations are significant due to temperature and downstream flow requirements, based mostly on the 2009 BiOp. For this reason, the differences between scenarios are not large. However, a comparison of the impaired and unimpaired flow data allows for several general conclusions about the impact of BDCP on key attributes of Sacramento Valley flow regimes:

Winter Flood Pulse. With the exception of the American River, the winter flood pulse is significantly reduced over unimpaired conditions in the Sacramento Valley. The magnitude of this reduction reflects the size and operations of upstream impoundments relative to the total runoff of the watershed. The most dramatic impairment of winter flood pulses occurs on the Feather River where the pulse is virtually eliminated in most years. There are no substantive differences between LOS, HOS and NAA operations for winter flood pulses. The winter flood pulse is marginally higher under NAA at Freeport, but this reflects more frequent flows down the Yolo Bypass.

Spring Snowmelt Pulse. The rise and gradual recession of flow in the spring is, next to low baseflow conditions in the late summer, the most predictable element of the Sacramento Valley flow regime and is of high biological significance. As shown in Figures 4.2A-D, the spring snowmelt pulse is highly impaired due to impoundments and flow diversions. With the exception of the Feather River, there are no substantive differences between HOS, LOS and NAA impacts on the spring snowmelt pulse in the Sacramento Valley. On the Feather, HOS flow operations designed to improve spring outflow in the Delta, lead to significant improvement in spring conditions in all but dry and critical year types.

Summer/Fall Baseflow. The timing and magnitude of reservoir releases dominates the summer/fall flow regime of the basin (Figure 4.2A-D). These releases are to meet the complex array of temperature and flow requirements downstream of the dams, irrigation demands upstream of the Delta, inflows to meet export demands, and outflows to meet water quality and habitat standards. Summer/fall baseflow flow regimes are highly altered with flows three to five times higher than unimpaired flows. With the exception of the Feather River, BDCP does not change summer/fall baseflow conditions. Under HOS and LOS simulations, the summer flows on the Feather are reduced, creating marginal improvement in flow regime.

Main Rivers Summary. The plan area for BDCP is, by design, limited in scope. The same applies to its conservation measures. The project Plan documents make it clear that operations of the CVP and SWP reservoirs are governed by BiOps or FERC licenses, and not BDCP. In addition, they note limited flexibility in reservoir operation due to cold water pool management, particularly on Shasta and Folsom Reservoirs. In this way, the reservoirs are in effect another constraint on BDCP (Chapter 3), rather than an asset for management.

Yet operations of these reservoirs greatly impact winter- and spring-run Chinook habitat downstream. As shown above, these operations contribute to the significant impairment of flows of the Sacramento River and its major tributaries and are a challenge when trying to meet the biological objectives of BDCP. Additionally, these dams block access to holding, spawning and rearing habitat that has far-reaching effects on winter- and spring-run Chinook salmon populations (Williams, 2006, 2009). These dams also support mitigation hatcheries whose operations may be contributing to harm of native salmon (Moyle et al., 2011).

It is unclear to us how to disentangle the relationship between the impacts of BDCP—a project designed to meet CVP and SWP water supply needs and an array of associated biological goals and objectives—and operations of SWP and CVP reservoirs. It seems logical to include these reservoirs in BDCP and operate them, along with the new facilities, under a single HCP/NCCP. The modest improvement in Feather River flows not withstanding, the result of this administrative separation is, in effect, to maintain the status quo for the highly impaired flows of the Sacramento system.

Yolo Bypass Flows

One of the more prominent conservation measures (CM#2) of BDCP is the modification of the Fremont Weir to promote increases in the frequency of winter and early spring inundation of the Yolo Bypass. A well-established and growing body of evidence, involving monitoring data, field experimentation and, to a lesser extent, life cycle models indicate high benefit of floodplain habitat to foraging juvenile salmon (see BDPC documentation for a full summary). This stems from the use of high value, off-channel habitat by juveniles, who, under optimal bioenergetic conditions and low predation pressures grow at high rates, increasing their survivorship through the Delta. Fish that either forage on the Yolo Bypass and/or use it as a migration corridor will not be impacted by near-field effects of the proposed North Delta diversion facilities. Fish using the Bypass are also less likely to enter the interior of the Delta where predation pressures are high. Finally, juveniles that use the Bypass leave the Delta later in the season, increasing the likelihood of arriving at the ocean during higher upwelling periods with better food availability.

Currently flow onto the Yolo Bypass from the Sacramento River only occurs when the Verona gauge exceeds 55,000 cfs. Modifications to the Fremont Weir would allow 1,000 cfs to flow onto the floodplain when flow at Verona exceeds 25,000 cfs. Flow through the Weir would climb to 6000 cfs when the river approaches 55,000 cfs. Above 55,000 cfs flow into the Bypass would be similar to NAA conditions. In addition to allowing flood flows, the weir would be modified to allow 100 cfs attraction flows to a fish ladder to improve upstream passage of adult salmon, steelhead and sturgeon (passage issues not evaluated here).

The average annual flow of the Yolo Bypass is approximately 1.5 maf. Under NAA, HOS and LOS, this amount would not differ significantly since the majority of flow volume on the Bypass occurs when the Sacramento overtops Fremont Weir and the

Sacramento Weir (Figure 4.3). However, the timing, frequency, and duration of floodplain inundation—key elements of the natural flow regime--would change substantially with the proposed modification of Fremont Weir.

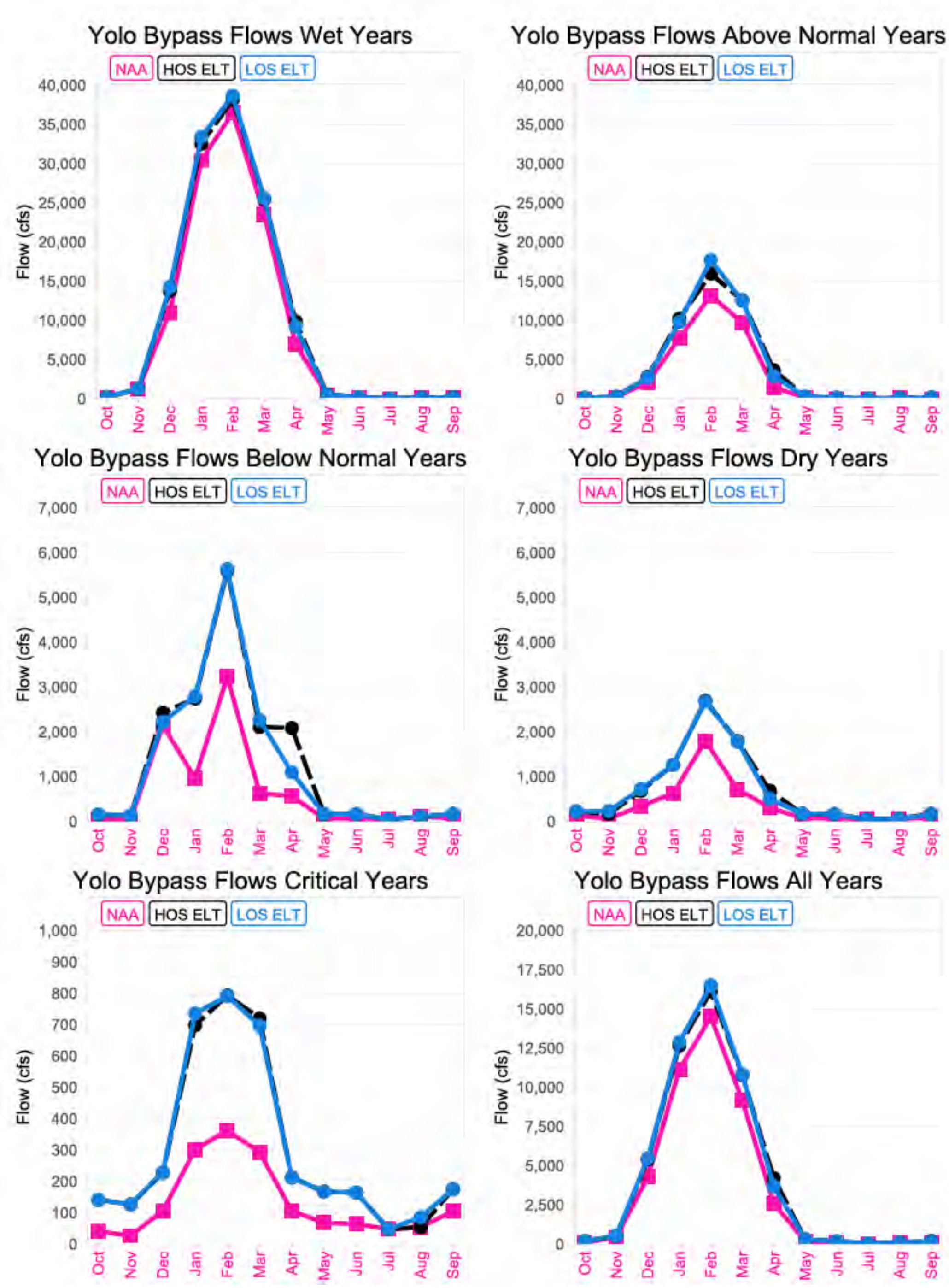

Figure 4.3: Average monthly flows for the Yolo Bypass under HOS, LOS and NAA under ELT conditions for different year types. Note changes in scale.

Flood Frequency. The frequency of inundation of the Bypass increases significantly under BDCP. Under current conditions there is a roughly 40% annual probability of flooding on the Yolo Bypass. Under BDCP this increases to more than 70% annual probability (BDCP statistics). The largest change occurs in drier years (Figure 4.3).

Flood Duration. Multiple studies have shown that flood duration, which allows for nutrient cycling and primary production, is essential for supporting juvenile salmonid foraging (Sommer et al., 2001; Williams, 2006, 2009). Modifications to Fremont Weir increase flood durations with high habitat benefits. Under current operations, flood durations aggregate to an average of 25 days per year. This would not change under NAA in the ELT. Under both HOS and LOS ELT this would increase more than three-fold to an average of 81 days per year.

Flood Timing. In addition to more frequent, longer-lasting flooding conditions, modifications to the Fremont Weir would expand the flood season, particularly in drier years (Figure 4.3). This expansion helps divert early migrants, such as winter-run Chinook salmon and later migrants, such as spring-run and fall-run Chinook, onto the floodplain. For example, based on BDCP data, we estimate that days of flooding above 1000 cfs on the Bypass will more than double in January and triple in April.

Yolo Bypass performance for listed salmon

Although CM#2 achieves the broader objective of improving the amount and quality of floodplain habitat, principally by restoring a more natural flow regime, it's effectiveness in supporting federally listed species of salmon (the focus of this review) is somewhat limited. The BDCP consultants modeled the overall benefits of the Yolo Bypass flows to out-migrating and foraging juveniles. For winter-run Chinook salmon, the benefits were modest with an estimate 1-8% increase in escapement. The limited benefit of the Yolo Bypass is, according to the BDCP model results, due to the small percentage of juveniles likely to be diverted onto the floodplain. This stems from the fact that most migration begins in December and January coincident with the first pulse flows of the season and does not coincide with peak inundation periods of the Bypass.

Greater benefit, albeit still limited, occurs for spring-run Chinook salmon. The bulk of juvenile out-migration takes place during the optimal months for floodplain inundation: February through March. However, two factors reduce the effectiveness of Yolo Bypass for spring-run according to BDCP documents. The majority of spring-run Chinook salmon come from hatcheries in the Feather River. Juveniles leaving the Feather are only diverted onto the Yolo Bypass during rare high flow events, leaving the Sacramento River as their principal migration route to the Delta. Naturally spawned fish in Butte Creek use the Sutter Bypass as their principal migration route. Like Feather River fish, they too only move access the Yolo Bypass during rare high flow events. Naturally spawned spring-run in Battle, Clear, Mill and Deer Creek pass Fremont Weir on their out-migration paths and will benefit most from likely access to the Bypass.

Second, according to BDCP models, most spring-run juveniles reach the Delta, and presumably the Yolo Bypass, as yearling smolts. In this stage, they are presumed by BDCP consultants to not take full advantage of the high quality foraging conditions of the Bypass, but use it principally as a migration corridor. BDCP consultants estimate that 90% of spring-run Chinook in the Yolo Bypass are migrants, rather than foraging fish. The BDCP consultants readily note that this proportion reflects the split between migrants and foraging characteristics in hatchery fish and may not be indicative of proportions of wild fish. Our consultation with several salmon biologists suggests that the distinction between foragers and migrants is arbitrary and likely does not reflect actual behavior of juveniles on the Bypass. In addition, there is emerging evidence that a high percentage of naturally spawned fish move out as fry and migrate during high winter flows (*pers. comm*., P.B. Moyle, 2013).

The BDCP consultants used several approaches to model the effect of the Yolo Bypass on survivorship. They acknowledge that current modeling tools are not well-suited to this kind of analysis. They developed a simple bioenergetic model for floodplain rearing, but told the panel that they felt it did not fully capture the benefits of the Bypass, and that their estimates of survivorship were conservatively low. Despite these limitations the BDCP models along with a growing body of literature suggest that spring-run juveniles as well as winter-run juveniles that access the Bypass are likely to have significantly higher survival rates to Chipps Island and presumably higher adult escapement[2].

Yolo Bypass Summary

CM#2 has high potential to benefit a range of covered species. Its benefit for winter- and spring-run Chinook is muted due to outmigration timing (winter-run) or the structural difficulty in diverting Feather River and Butte Creek fish (spring-run) onto the Bypass. Yet even with these concerns, there are likely to be improvements in survivorship associated with an alternative migration corridor with high value foraging habitat. There is an adaptive management program being developed for the Yolo Bypass that will be incorporated into BDCP. This effort would benefit BDCP objectives by conducting experiments and modeling that test ways to improve access of listed salmon onto the Bypass. This can include modifications to the Fremont Weir or pulse flow releases that improve winter-run diversion. Along with modification of Fremont Weir, this program may also want to consider the potential for using the Sacramento Weir to divert Feather River and Butte Creek fish. Regardless, as outlined below, a more aggressive approach to developing an alternative migration corridor for winter- and spring-run Chinook is likely to be necessary to mitigate the effects of the new North Delta facility.

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[2] The focus of this chapter is on spring- and winter-run Chinook. There is very significant benefit to other covered species, particularly fall-run Chinook and Sacramento splittail that can take advantage of Yolo Bypass flooding more readily.

North Delta Facility Impacts and Mitigation

The new point of diversion along the Sacramento River is likely to impact all covered fish that either use the main channel of the Sacramento for migration or rearing, or are indirectly affected by downstream changes in flow volume and timing. These impacts are some of the most difficult to assess due to uncertainties about design and operation of the facilities (no comparable facility exists to calibrate models) and the relationship between downstream actions, such as tidal marsh restoration, and flows. This section assesses BDCP's evaluation of near-field (adjacent to the facility) and far-field (downstream from the facility) effects.

Near Field Effects

The preferred project involves the construction of three screened intakes along the left bank of the Sacramento River in the vicinity of the town of Hood. Each screen will be capable of withdrawing up to 3000 cfs. In our view, the BDCP consultants have properly identified the two main sources of near field effects of the facility on out-migrating salmonids: losses due to impingement on the intake screens and losses due to predation near the diversion. However, we are uncertain about the effectiveness of proposed mitigation for these effects.

To mitigate for impingement potential, the consultants propose real-time management of pumping regimes relative to channel flow in order to maintain approach and sweeping velocities that reduce contact with intake screens. This real-time management would be informed by upstream monitoring of outmigrants. This issue remains a high uncertainty for operations of the facility ("low certainty" in the parlance of BDCP). Conceptually, a good adaptive management and research program coupled with real-time management could reduce impacts. However, as of this writing, the specifics of this program are not provided by BDCP (see discussion in Chapters 8, 9 this report) and we are unable to evaluate how effective it might be.

A greater near field effect of the facility is the high likelihood of concentration of predators near the facility, with resulting losses of migrants and foragers due to predation. Predators take advantage of concentrated prey and velocity refugia at physical structures throughout the Delta (Vogel, 2008) and will presumably do the same at the North Delta intake facilities. The BDCP consultants use various modeling approaches to estimate potential predation losses, including comparison with estimates of losses at known structures such as diversion screens of the Glenn-Colusa Irrigation District. Estimated predation losses for juvenile winter run Chinook that pass the facility vary from as low as 1% to as high as 12% (we did not find statistics for spring-run Chinook salmon losses). The higher predation loss values would have significant population-level impacts on winter-run Chinook and would fail to meet objectives of BDCP. The consultants acknowledge high levels of uncertainty about predation effects at the facility. The solution, as with most issues with high uncertainty in BDCP, is to defer this to adaptive management of the project, including unspecified predator control programs and real time management of flows. Based on our experience in the Delta, we consider this to be a significant, unresolved management issue.

Far Field Effects

The North Delta facility is expected to provide an average of roughly half of the exports from the Delta. As outlined in Chapter 3, operations of the facility are highly constrained by flow and water quality regulations, upstream water use, reservoir operations and hydrology. The simulated operations of the North Delta facility are summarized in Figure 4.4, including a measure of the proportion of channel flow that is diverted.

There are significant seasonal and interannual variations in operation of the North Delta facility that will drive far field effects[3]. During wet and above average water years, pumping regimes are most aggressive, particularly during the summer and early fall when 25% to as much as 39% of channel flow is diverted. Diversions, as a percentage of channel flow, decline dramatically in below normal, dry and critical years. In addition, pumping regimes are highly protective of channel flow in December, reflecting the restrictions on exports to protect initial pulse flows for winter-run Chinook. As expected, the HOS scenario, designed to improve Delta outflow, results in the most protective pumping regime for bypass flows at the North Delta facility.

BDCP documents acknowledge that the reductions in bypass flow create multiple far field effects that impact listed salmon. These include reduced attraction flows for migrating adult salmon, increased losses of juvenile salmon migrants and foragers due to longer transit times to the Delta, and diversion into the interior Delta where predation and/or entrainment losses are high. These operations also affect total Delta outflow[4].

The BDCP consultants use multiple modeling approaches to address the far field effects of the North Delta facility. The main model used is the Delta Passage Model (DPM) that tracks smolt survival through the Delta. This model and others summarized in Appendix 5C of the Effects Analysis all draw the same conclusion: there is an increase in losses of winter- and spring-run Chinook salmon migrants associated with reduced flows in the bypass reach from Hood to Rio Vista. The magnitude of this impact varies depending upon year type (wetter years have reduced losses) and magnitude of flow reduction associated with pumping (up to 35% decreases in flows during some migration periods). These results are not surprising since there is a long-established relationship between transit time and

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[3] We did not evaluate the effects of size of the facility and its level of use. However, it is worth noting in Figure 4.4 how often average monthly exports approach facility capacity. Using a monthly average greater than 8000 cfs as an indicator of periodic use of full capacity, this only occurs in February and March in wet years and March of above average years. This is roughly 5% of the total months, suggesting that operational and regulatory constraints, rather than facility size, determine export volumes.

[4] Appendix B presents a summary of Delta outflow and the magnitude of impairment of flows from the Sacramento Valley. The latter uses a simplified impairment index.

survivorship for smolts leaving the Sacramento River (Newman, 2003; Perry et al., 2010).

Figure 4.4. Average monthly export flows of North Delta diversion facility under HOS and LOS ELT for different year types, and percentage of total bypass channel flow exported.

BDCP proposes to mitigate the increase in losses of smolts associated with far-field effects through six strategies:

- Tiered pumping regimes to reduce withdrawals during the initial winter flood pulse (described in Chapter 3)

- Real-time operational changes that reduce export pumping when monitoring indicates that large numbers of migrants have entered the reach upstream of the facility
- Flow management that reduces tidal reversals at Georgiana Slough, decreasing the likelihood of smolts diverting into the interior of the Delta
- Non-physical barriers at Georgiana Slough
- Reductions in entrainment at the South Delta facility due to reduced export pumping
- Increased diversion of foragers and migrants onto the Yolo Bypass
- Improved channel margin, floodplain and tidal marsh habitat to support foraging juveniles

The benefits of the last of these strategies—habitat restoration—are not captured in the survivorship modeling that was completed by BDCP consultants (see chapter 7 for a discussion). In addition, the models do not incorporate real-time operations adjustments since the scope and terms of these operations have yet to be determined. The remaining strategies are incorporated into models used to assess smolt survivorship. Closely examined, BDCP model results indicate that these measures, in combination, roughly offset the losses created by reductions in flows and increases in predation in the bypass reach, meeting the standard of mitigation. There is no indication that these actions would result in substantial improvement in conditions for listed salmon. This includes the Yolo Bypass, which provides significant benefits for other covered species.

North Delta Facility Summary

We have not had sufficient time or resources to conduct a detailed review of the models used to assess survivorship in the bypass reach and the effectiveness of mitigation efforts. Overall, most of the models used for near and far field impacts are standard Delta models. Model results seem reasonable and fall within the boundaries of current understanding. This suggests that they provide an acceptable first-order approximation useful enough as a basis for further analysis and adaptive management experiments.

We view the efforts to model the effectiveness of predator management and non-physical barriers as having high uncertainty. In addition, as noted, there is insufficient detail on real-time management to assess its likelihood for success. The flow modeling that was done on the bypass reach makes assumptions about tidal marsh restoration in the Cache Slough area. This restoration plays an important role in tidal energy and efforts to manage flow reversals at Georgiana Slough. We are uncertain about both the impact of this tidal marsh restoration and, if modeled correctly, whether the assumed restoration would be completed in the ELT. This same issue applies to the Yolo Bypass. Scheduling contained in BDCP suggests that the Yolo Bypass project would not be complete until after the North Delta facility. This lag in completion hampers efforts to mitigate for the project. At minimum, given the large uncertainties, it seems prudent to have all mitigation efforts in place and tested prior to initiating operation of the diversion facilities.

Conclusion

To meet its biological goals and objectives, BDCP has developed 22 conservation measures. Two of these measures—CM#1, Water Operations, and CM#2, Yolo Bypass—are intended to create significant improvement in conditions for covered fishes by creating more natural flow conditions, improving fish passage and, in the case of the Yolo Bypass, improving floodplain spawning and rearing habitat. We focused our assessment on how CM#1 and CM#2 performed for winter and spring-run Chinook in this regard.

In general, we found that CM#1 does not significantly change the highly impaired flow regime upstream of the Yolo Bypass and Freeport, with the exception of an increase in spring flows on the Feather River under the HOS flow scenario (nor does it change outflows much as shown in Appendix B). BDCP proponents have made the strategic decision to focus principally on the Delta, rather than including CVP and SWP reservoirs that regulate flow into the Delta. This limits BDCP's effectiveness in its conservation measures since it does not address the major risk factors for listed salmon.

We found the increased frequency of flows into the Yolo Bypass to be an important step in restoring floodplain habitat. However, timing of outmigration and current design of CM#2 modifications limit the impact of this effort for listed salmon. The current adaptive management program underway for the Yolo Bypass needs to address this issue, including considering changing reservoir operations and alternative ways to divert fish into the Bypass.

Near field and far field effects of the North Delta facility have the potential to significantly reduce survivorship if not fully mitigated. Uncertainties over mitigation are high and will require a robust adaptive management plan. In our view, the Yolo Bypass program should be viewed as mitigation for the impacts of the North Delta facility on listed salmon. CM#2, along with all other mitigation efforts, need to be in place prior to operation of the facility.

Chapter 5: In-Delta Flow Performance

Introduction

BDCP Conservation Measure #1 (CM#1) aims to restore more natural net flows (i.e. net seaward) within the Delta by adding a point of diversion upstream of the Delta:

> Conservation Measure #1: "Construction and operation of the new north Delta intakes are designed to substantially reduce the incidence of reverse flow (Section 3.4.1.4.3, *Flow Criteria*) and restore a predominantly east-west flow pattern in the San Joaquin River. (Page 3.4-7, emphasis added).

This statement implies two classes of presumed effects that south Delta diversions induce through altered flows: direct effects whereby reversed flows in the south Delta contribute to entrainment of fish at the Delta export facilities, and indirect effects whereby changes in flow in the lower San Joaquin River are believed to alter the survival or migratory success of fish in the affected channels. Both of these presumed effects refer to net flows, which are determined by averaging out the substantial tidal flows that reverse direction twice daily. Although these net flows are small compared to tidal flows in much of the Delta, there is evidence that they can have substantial effects on some fish species.

In this chapter we evaluate changes in net flows in the Delta associated with changes in operations and the construction of the new facility. As in Chapters 3 and 4, we evaluate the differences between HOS and LOS scenarios and compare then to NAA, the no-action alternative. All of these analyses are in the Early Long-Term (ELT) shortly after the beginning of operations of the North Delta facility.

Concerns over modeling

As noted in Chapter 1 of this review, we have concerns over the use and over-interpretation of the modeling data provided to us. In conducting our analysis for this chapter and the following chapter on impacts of outflows on smelt, we have relied on output from CALSIM under various scenarios. Our analysis revealed several apparent anomalies in model output. Although we received clear explanations of the origin of these anomalies from the BDCP consultants, we remain concerned that the model output is unrealistic for projecting actual project operations and the resultant flows. In particular, certain modeled conditions arise through artifact that provide substantial improvements in conditions for delta smelt. Thus, conclusions drawn on the basis of these models rest on an unreliable foundation. These concerns are focused on Delta outflow during fall and southward flow in the southern Delta during winter. These flows have been linked to habitat and survival of delta smelt.

October

The USFWS Biological Opinion for delta smelt includes a fall X2 standard that applies following wet springs. Flows are usually low during this season so small variations in flow can have substantial effects on the location and area of the low salinity zone, and hence potentially on habitat conditions for smelt.

For various reasons X2 calculated by CALSIM differs substantially from that determined from outflow as in Jassby et al. (1995). We therefore focused on outflow as determined by CALSIM, rather than X2 as provided by BDCP modelers.

For this analysis we sorted flow data into a ranked series from lowest to highest values of Delta inflow under NAA. In Octobers of most years in the drier half of the series, outflow under HOS and LOS is up to twice that under NAA (Figure 5.1; median 77% higher for these 41 years). By contrast, during years of high inflow (right-hand half of Figure 5.1), HOS and NAA outflows roughly track each other, while LOS is much lower because the fall X2 requirement does not apply to that scenario. The anomaly occurring under dry conditions is not balanced by flows in other fall months. A few anomalies like those found in October crop up in November, but otherwise in those months either all three outflows track each other or LOS is lower.

To our knowledge there is no regulatory or operational requirement for reduced outflow under NAA or increased outflow under HOS or LOS in dry Octobers. Furthermore, there would be no reason to focus such a requirement in only one month if it were meant to benefit delta smelt, since they are present in the low-salinity zone from summer through fall. Outflow in fall can affect delta smelt recruitment so the modeled outflows can result in considerable differences in predicted recruitment under the three modeled scenarios (Chapter 6). We do not find these differences compelling because of a lack of a regulatory or other basis for the high outflows under HOS and LOS in dry Octobers.

January

January has been the month of greatest adult delta smelt entrainment historically, so the modeled conditions in January can have large impacts on forecasts of adult survival. The CALSIM modeling included a requirement that OMR flows during January be zero in wet years, no more negative than -3500 in above-normal and below-normal years, and no more negative than -5000 in dry and critical years. However, no estimates of current year type are possible in January, and rather than presume perfect foresight or use information available up to that point the modelers chose to operate the simulated system for January using the requirements that applied to the previous year type. Because dry Januaries can follow wet years, this resulted in an anomalous condition in which requirements for wet years applied during dry Januaries.

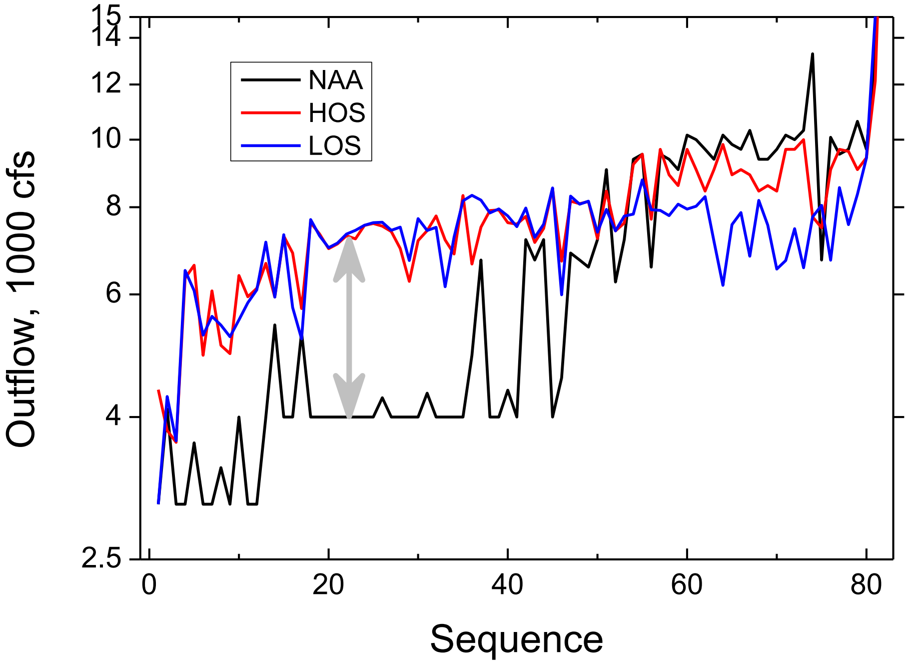

Figure 5.1. Net Delta outflow in October under the three scenarios sorted by inflow as determined by CALSIM under NAA; i.e., sequence 1 is the lowest inflow and 82 the highest. The gray arrow points out the region of interest where outflow under HOS and LOS is as much as double that under NAA. Outflow is plotted on a log scale to show proportional differences among scenarios especially at low flows, and because X2 can be modeled as a function of the log of outflow. The highest two outflows have been cut off to focus the figure on the lower values.

As a result of this anomaly, the modeled scenarios (LOS and HOS) called for reductions in export flows in Januaries following wet years, which substantially increased OMR during many Januaries at the dry end of the historical range for that month (Figure 5.2). This is unrealistic for several reasons. First, the actual values don't conform to the model requirements of 0, -3500 or -5000 cfs, depending on previous year type; instead they are quite variable and achieve zero rarely. Thus, there is no clear regulatory basis for these flows.

Second, the reduction in export flows was sometimes accomplished through increased outflow rather than reduced reservoir releases or increased exports from the North Delta (Figure 5.2). Thus, many January outflows during dry periods were much greater than the corresponding flows of the NAA alternative.

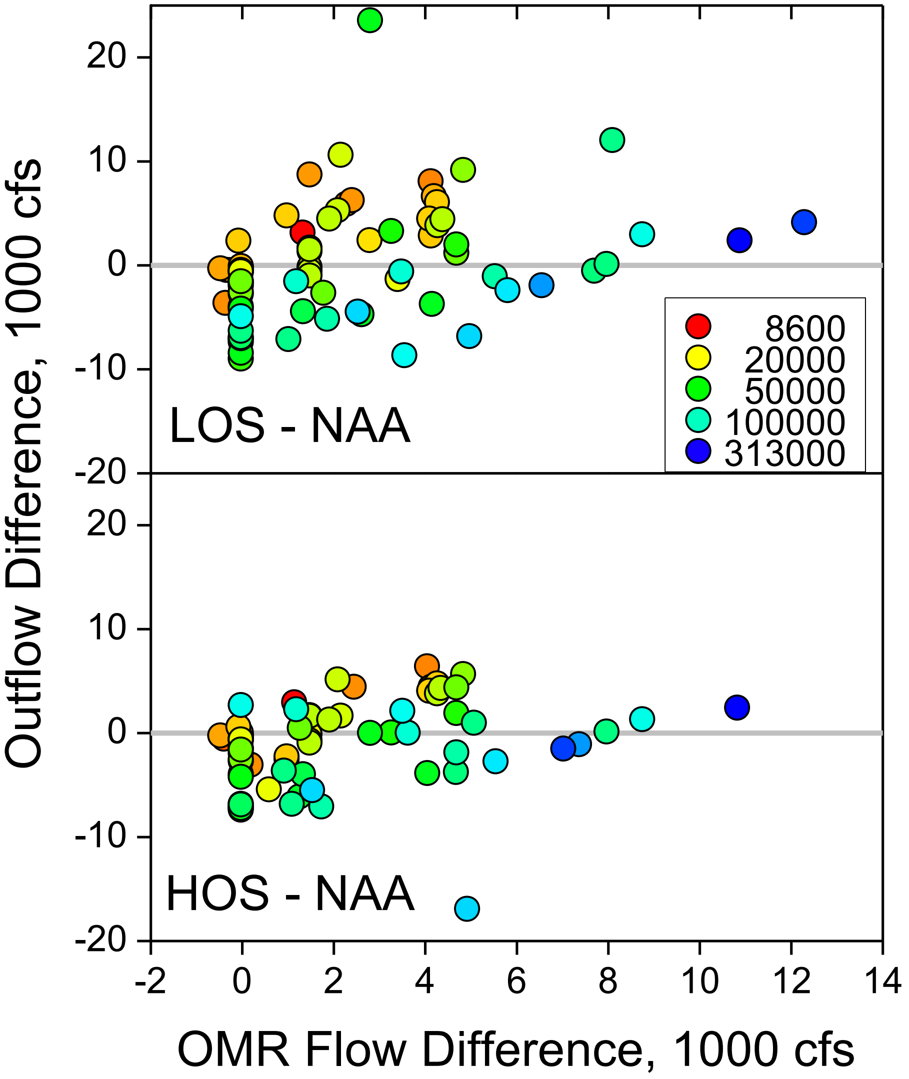

Figure 5.2. January flow conditions compared between the two modeled scenarios (LOS, top; HOS, bottom) as the differences from the flows under NAA. The colors show the range of NAA inflow. Under the LOS there were many Januaries when inflow was low but the outflow and OMR flow were increased by about the same amount over NAA.

Consequences

The anomalies discussed above seem to arise through the application of rules and constraints designed in some cases for real-time operations, using a model with a monthly time step. We understand and appreciate the difficulty in modeling such a complex system and the problems that would arise in attempting to mimic variation on a daily time scale. Furthermore, we trust that the modeling team has made every effort to produce output that conforms to the constraints and the modeled hydrology. Nevertheless, the specific model outputs we focus on above seem unrealistic, particularly since these anomalies are largely confined to October and January. We do not think the system is likely to be operated in real time to achieve the flows shown in model output.

Thus, discussions in this and the next chapter should be accompanied with this caveat: *these apply only if the system were actually to be operated to achieve the flows indicated by the models*. If rules are not in place to ensure these flows are achieved, the benefits to delta smelt (and presumably other species) will not be realized.

Analysis of flows

Construction of a new export facility will not by itself achieve the goals of restoring more natural flow patterns in the Delta; the effects of such a facility are entirely dependent upon its operational rules. We assessed how much the modeled operational scenarios (HOS and LOS) achieve the goals of restoring net natural flow directions within the Delta. In recent years, the Biological Opinions for delta smelt and salmonids have directed attention to net flows in OMR, which are the main channels carrying Sacramento water to the export facilities in the south Delta. OMR flows show relationships with salvage of some fish species at the fish facilities and are presumed to reflect entrainment risk to fish in the Delta, i.e. the direct effects of the projects. In earlier years, focus was on net flows in the lower San Joaquin River (QWEST) as a more general measure of the impacts of water management on net flows in the Delta, which were believed to cause indirect effects on fish populations.

OMR and QWEST flows are two measures for the effectiveness of CM#1 in restoring more seaward flows in the Delta (see Chapter 6 for an estimate of effects of the modeled flows on delta smelt entrainment). Here we examine both the changes in seaward flows and the degree of negative flows as predicted from CALSIM models.

A north Delta diversion will increase the frequency of positive net OMR and QWEST flows and reduce negative values to the extent that exports from the north Delta reduce exports from the south Delta. However, BDCP calls for continued use of south Delta diversion facilities and greatly restricts the operation of the north Delta diversion, particularly in dry periods and early winter. Thus, restoration of seaward flows in the Delta must be viewed in the context of the timing and conditions when the north Delta diversion can be used.

We describe how LOS and HOS alter the incidence and degree of reverse flows during the seasons of sensitivity for the covered fish. For each season of sensitivity, we group results by quartiles of outflow to assess how changes in flows occur under drier vs. wetter conditions. Low flows in the winter and spring are when concern over reverse flows is greatest for most species.

Direct effects

Direct effects are entrainment, or the number of fish diverted into the facilities. This number is not known for any species because substantial numbers of fish are lost in the waterways leading to the fish facilities and through the louvers at the fish facilities. Salvage is therefore a poor measure of entrainment effects, but there are no other direct measures. Estimates of entrainment as a proportion of total population of delta smelt are presented in Chapter 6. Such an analysis has not been developed for any other species of concern. Therefore, to broaden the analysis to all species we examined changes in modeled flow in OMR. This measure has been used in both Biological Opinions. OMR flow is both calculated by models and measured in the field; it is roughly equal to San Joaquin River inflow minus total exports. Because San Joaquin inflows are less than total exports under all but flood conditions, OMR flows are usually negative. We assume OMR is the primary focus of CM #1's goal to "reduce the incidence of reverse flow". To broaden the question we also assess the degree to which flows are made less negative by the alternatives.

Incidence of reverse flow

Because 'incidence' is a measure of frequency, the "Incidence of reverse flows" is the frequency with which OMR is changed from negative under NAA to zero or positive (northward) under the proposed alternatives; because model output is available by month, we examined frequency on a monthly basis (Table 1). The distribution across months of the change in net OMR direction implies that effects on each species will depend on its season of sensitivity.

The results below are consistent with the goal of CM#1 of achieving a greater frequency of positive net flows in Delta channels by shifting exports to the north Delta diversion site. This is true more for HOS than LOS operations.

LOS effects. The LOS reduced the incidence of negative flows by 5% overall (50 months out of the 984 months modeled; Table 1). Under NAA 110 months had positive (northward) OMR flows while 160 months had positive flows under LOS. Positive or zero OMR flows under LOS coincided with negative flows under NAA in all months save August, but most frequently in January – March. There were 21 months when OMR flows were positive under NAA but negative under LOS in April and May (Table 1).

The shift to positive OMR flows under LOS was sometimes quite large (about 6000 cfs) and occurred almost solely under higher river inflows during December through June. The occasions when NAA alone produced positive OMR flow occurred only in April and May and the change in OMR flows between NAA and LOS were small (<1000 cfs).

HOS effects. The HOS had a more substantial effect on the incidence of negative flows than LOS (Table 1). There were only 13 instances when positive OMR flows under NAA were negative under the HOS, and the differences were very small in those cases. As with LOS, the changed OMR status happened in all months save August. The most noticeable difference between HOS and the other two alternatives was in September and November when HOS was northward about a third of the time while NAA was always southward and LOS northward only a few times. The low frequency of northward flows under HOS in October may be related to the anomalies in outflow identified above, but the reasons for the otherwise high frequency of positive OMR flows in fall under HOS are obscure, as they are not called for by regulations and no fishes of concern are vulnerable to export entrainment at that time.

Table 1. Frequency by month of northward (including a few zero flows) or southward flows under NAA vs. LOS, and NAA vs. HOS. Columns in italics indicate those years and months when the direction of flow differed between NAA and the selected scenario. For example, in April there were 47 years when NAA flow was northward, in 5 of which LOS was southward, and 35 years when both flows were southward, out of a total of 82 years.

Month	**NAA North**		**NAA South**		**All LOS North**	**NAA North**		**NAA South**		**All HOS North**
	LOS North	*LOS South*	*LOS North*	LOS South		HOS North	*HOS South*	*HOS North*	HOS South	
Oct	0	*0*	*1*	81	**1**	0	*0*	*8*	74	**8**
Nov	0	*0*	*2*	80	**2**	0	*0*	*25*	57	**25**
Dec	3	*0*	*1*	78	**4**	3	*0*	*0*	79	**3**
Jan	4	*0*	*11*	67	**15**	4	*0*	*12*	66	**16**
Feb	8	*0*	*18*	56	**26**	8	*0*	*19*	55	**27**
Mar	6	*0*	*25*	51	**31**	6	*0*	*36*	40	**42**
Apr	42	*5*	*0*	35	**42**	44	*3*	*5*	30	**49**
May	25	*16*	*0*	41	**25**	31	*10*	*6*	35	**37**
Jun	1	*0*	*9*	72	**10**	1	*0*	*9*	72	**10**
Jul	0	*0*	*1*	81	**1**	0	*0*	*1*	81	**1**
Aug	0	*0*	*0*	82	**0**	0	*0*	*0*	82	**0**
Sep	0	*0*	*3*	79	**3**	0	*0*	*38*	44	**38**
All months	89	*21*	*71*	803	**160**	97	*13*	*159*	715	**256**

Magnitude of negative OMR flows

Entrainment rates are a function of population distribution and abundance, season of occurrence in the Delta, and flow conditions including export rates (or OMR conditions). The months of vulnerability for each species of concern were taken from the BDCP documents. For adult longfin and delta smelt the season of vulnerability is from December through March. For juvenile delta smelt the season is from March through June.

The effects of overall flow conditions, i.e. how relatively wet or dry it is, were assessed by grouping the months of vulnerability for all 82 modeled years into quartiles of outflow in the NAA; e.g., for adult delta smelt which are considered vulnerable during December-March, there were 82 months in each quartile of outflow. We examined conditions of OMR, river inflow and outflow under several operational scenarios. We examined differences under four levels of wetness for each month using outflow in the month as a measure of wetness. Historically fish are more often salvaged under drier conditions than under.

In Figure 5.3 we present comparisons of the HOS and LOS scenarios for each quartile of outflow (under the NAA scenario to ensure comparison of the same years in each graph).

Under the HOS and LOS alternatives, OMR differs from NAA during the seasons of sensitivity for adult delta smelt (Dec-Mar) and juvenile delta smelt (April-June).

Three patterns can be seen:

1. In the season of vulnerability for adult smelt (December – March), HOS and LOS both show about a 1000-5000 cfs increase toward positive in OMR under all quartiles of outflow, but all OMR values are strongly negative except in the wettest quartile of the data. Exports in December and January can be high and the use of a north Delta diversion can improve OMR (but see "Concerns over modeling" above). For juvenile smelt, the increase in OMR flow under LOS and HOS is smaller and less consistent. In all cases the level of OMR flow is much less negative than in December – March.
2. The HOS and LOS alternatives differ only slightly except during the drier periods when OMR flow is slightly less negative under HOS than under LOS.
3. Under wetter conditions all alternatives produce median OMR flows in the range targeted as protective in the Biological Opinions (more positive than -5000, but see Modeled Impacts on Delta Smelt in Chapter 6). The use of NDD under high-flow conditions allows the HOS and LOS to avoid the extreme negative OMR values that occur under NAA because of the high south Delta export rates that are possible then.

Thus, in summary, model results suggest that reverse flows in the south Delta become more positive under both LOS and HOS for all quartiles of outflow. These changes can be seen both in the frequency and in the distribution of flows in the two seasons of vulnerability and the four quartiles of NAA outflow. In wetter months the north Delta diversion does not fully replace south Delta exports until river inflows are relatively high, so that OMR remains negative in most months of smelt vulnerability. Changes in OMR during the period of vulnerability of young delta smelt are smaller than those during December – March because all alternatives are constrained by the Biological Opinions to a much higher baseline OMR flow.

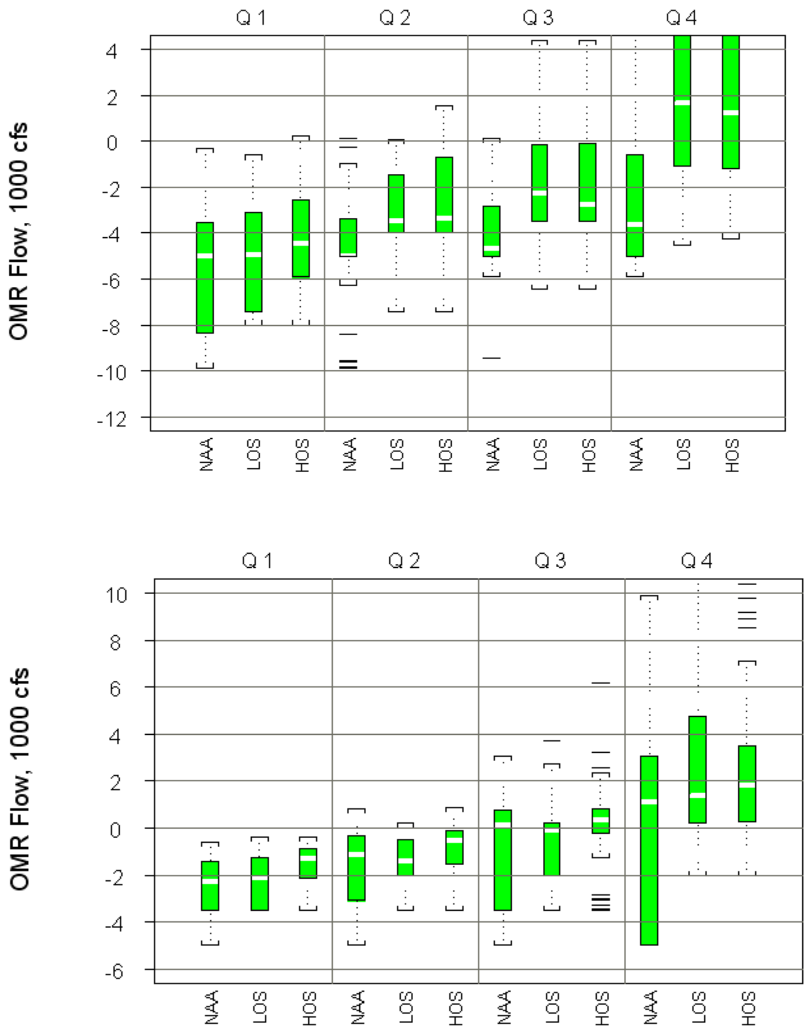

Figure 5.3. Values of OMR under the three alternatives for BDCP shown for quartiles of outflow under the No-Action Alternative. Boxes show first and third quartiles with the median as a white bar. The whiskers encompass points within 1.5 times the interquartile range, and the short lines are outliers. Top, period when adult longfin and delta smelt are vulnerable (Dec-March). Bottom, period when juvenile delta smelt are vulnerable (March-June).

Indirect effects

Net or tidally-averaged flow on the lower San Joaquin River at Jersey Point is parameterized as QWEST. This flow can be negative (i.e., eastward), which is considered an indicator of flow conditions unfavorable to fish. Negative QWEST could alter the speed or path of fish migrating through the Delta, thereby prolonging their migrations or making them susceptible to adverse conditions in the Delta. No field estimates of indirect effects have been made and they are conceptually difficult because the biological effects are difficult to define and because the net flows in the lower San Joaquin River are small compared to tidal flows. Nevertheless, regulatory agencies, particularly the CDFW and the

NMFS, have long expressed concern that negative values of QWEST due to project operations present fish with impediments to their effective migration.

The "east-west flow pattern in the San Joaquin River" referred to in the justification for CM#1 is apparently QWEST. QWEST is calculated in the Dayflow water balance program (http://www.water.ca.gov/dayflow/) as:

QSJR + QCSMR + QMOKE + QMISC + QXGEO - QEXPORTS - QMISDV - 0.65 (QGCD – QPREC),

i.e., the sum of inflows from San Joaquin River, eastside streams, and the Sacramento River via the Cross-Delta Channel and Georgiana Slough, minus south Delta exports, miscellaneous diversions in the Delta, and a fraction of the difference between precipitation and consumptive use within the Delta. However, for CALSIM modeling Delta consumptive use (QGCD), Delta precipitation (QPREC), and Delta miscellaneous diversions (QMISDV) are unavailable so the above equation simplifies to:

QWEST = QSJR + QMOKE + QCSMR + QXGEO – QEXPORTS.

QXGEO increases with Sacramento River flow and also depends on DCC gate operations. Specifically, QXGEO changes as 13.3% of Sacramento River flow with both DCC gates closed and 29.3% with both gates open (Dayflow documentation cited above). Sacramento River flow into the Delta will decrease by the amount diverted in the north Delta. Thus, among the flows controlled under BDCP, QWEST decreases by 100% of south Delta export flows and 13.3% or 29.3% of north Delta diversion flows depending on DCC gate positions.

There are many covered species of fish that migrate through or reside in the central Delta (Table 5.2). At least one of these species is present in the Delta during every month but August. Conditions in the central Delta are important for migratory species that spawn in the San Joaquin or Mokelumne Rivers because the entire population must pass through the central Delta. By contrast, only a fraction (unknown) of Sacramento fish enter the central Delta during migration. To cover the species that would be most affected by changes in flows in the San Joaquin River, we limit discussion to outmigrating salmonid juveniles (February – April) and upmigrating San Joaquin salmon (September – November).

Juvenile salmon

The occasional high springtime flow requirements of HOS (to benefit longfin smelt) coincide with the smolt emigration season (February – April). In drier conditions (the drier two quartiles) there is very little difference between NAA and LOS (Figure 5.4). The occasional occurrence of high flow requirements in HOS produce some differences between LOS and HOS scenarios, but mostly in the second quartile when the high flows are more likely to be triggered than in the driest quartile. All project scenarios diverge from the NAA under the wetter scenarios as more water is diverted from the north Delta and substitutes for high south Delta exports (Figure 5.4). The several thousand cfs differences in wetter months are occurring against baseline flows in the realm of 20000 cfs and greater, whereas the changes in flows in drier conditions are very small because limited North Delta diversion operations at low flows do not affect broad indices of Delta flow such as QWEST.

Table 5.2. Species of fish covered by BDCP that occur within the Central Delta for specific life history stages and the season of sensitivity to changes in flow conditions due to project operations (from various sources).

Species and Life History Stage within the Delta	Timing
Sacramento and San Joaquin steelhead juveniles	February - April
Winter-run Chinook salmon juveniles	November - April
Spring-run Chinook salmon juveniles	March-May
Green sturgeon	November-December
Delta smelt adults	December-March
Delta smelt juveniles	April-June
Longfin smelt adults	December-February
Longfin juveniles	February-March
Upmigrating San Joaquin steelhead	September-April
Upmigrating spring-run Chinook salmon	March-August
Upmigrating winter-run Chinook salmon	January-May
Upmigrating fall-run salmon Chinook salmon	September-November

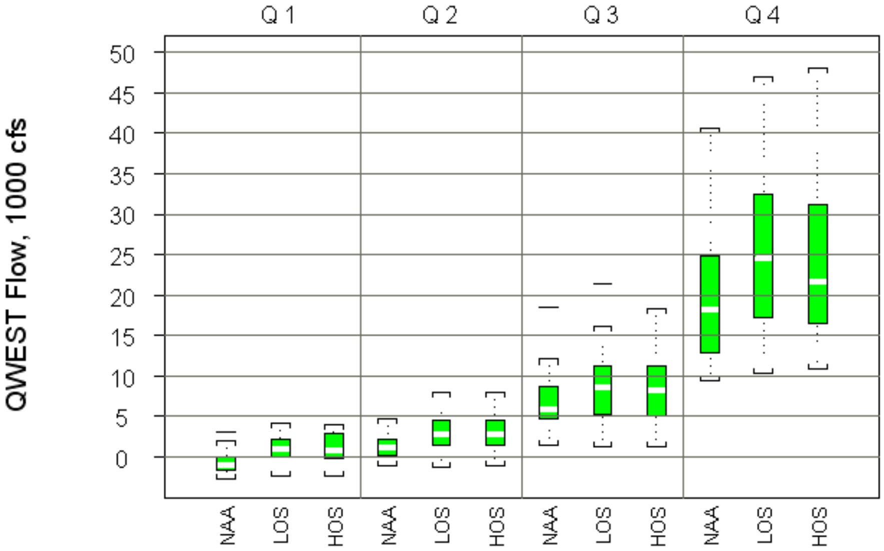

Figure 5.4. Feb-April QWEST flow for NAA and 3 alternative operational scenarios, grouped by quartiles of outflow. Two outliers for each scenario in Quartile 4, with values of 52,000 – 98,000 cfs, were cut off to allow better resolution of the lower values.

Adult San Joaquin fall-run salmon

Upmigrating salmon adults to the San Joaquin River pass through the south Delta and the lower San Joaquin River during September – November. In the fall there is very little difference among the alternatives that is not dwarfed by occasional high inflows due to flood releases or early winter storms (Figure 5.5). However, all alternatives show a general increase in QWEST compared to values for NAA because the use of the North Delta

Diversion is much less restricted and can more often substitute for south Delta diversions that are often operating at maximum flow under NAA.

In summary, project scenarios have small effects on QWEST in any season; changes in QWEST are smaller than those in OMR because use of the North Delta diversion does not translate into direct increases in flow, as it can for OMR. This is true for both the spring and fall. The high flows in HOS produce increases in QWEST in months around median wetness.

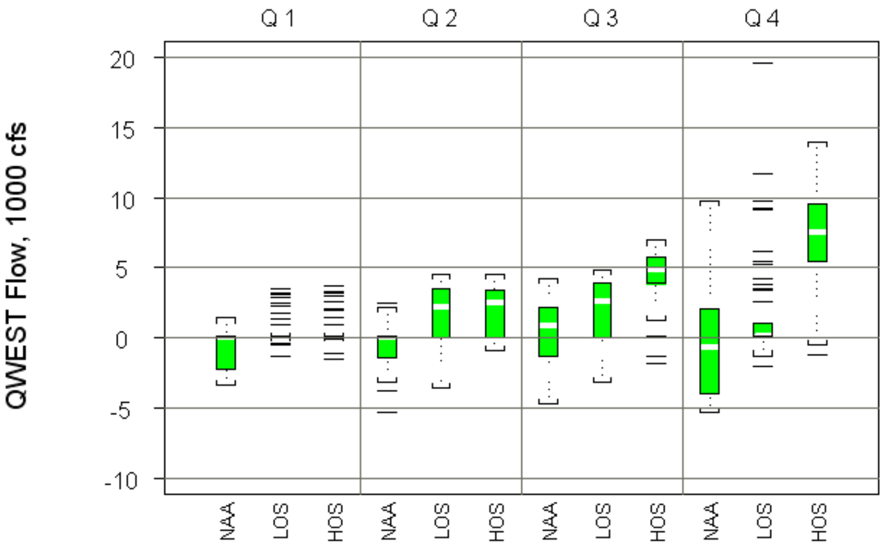

Figure 5.5. QWEST flows for the September-November season grouped by quartile of outflow. One outlier for each scenario in Quartile 4, with values of 22,000 – 30,000 cfs, was cut off to allow better resolution of the lower values.

Conclusion

The analysis presented here demonstrates broad improvement in in-Delta conditions under BDCP, as measured by changes in OMR and QWEST. However, we reiterate our concerns over the likelihood that Delta flows would actually be managed in the manner prescribed by the modeling. Changes in the frequency of reverse flows and their magnitude were somewhat obscured by the high variability among years, even those with similar hydrology. Some of this variability is a consequence of carry-over storage and the specifics of operational rules that may be triggered by conditions in one year but not another even if hydrology is similar. In the context of this variability, the improvements in flow conditions during periods of vulnerability of the smelt and salmon species were modest.

In analyzing model results of the operational scenarios we were surprised to see benefits occurring under dry conditions. The restrictions on North Delta diversions limit its operations to times of substantial river flows, so its ability to substitute for south Delta diversions should be limited to times of high flow. In fact, over a broad range of intermediate flows, the north Delta diversion augmented south Delta exports, rather than substituting for them. Thus, improvements to in-Delta flow conditions happened mostly in the highest quartile of Delta outflow under NAA. The differences between flows under the LOS and HOS were generally rather small.

Chapter 6: Estimated Effects of BDCP Flows on Smelt

Introduction

This chapter takes the model projections for three scenarios discussed in Chapter 5 (NAA, HOS, and LOS) and uses various simple statistical models to estimate the potential effects of these flows on delta and longfin smelt. The principal flows of interest are:

- Winter and spring flows in Old and Middle Rivers, which affect adult and larval to juvenile delta smelt, respectively
- Fall outflow, which may influence extent of habitat and therefore subsequent recruitment of delta smelt
- Spring outflow, which has a statistical relationship with subsequent abundance of young-of-the-year longfin smelt

We did not consider export effects on longfin smelt, for which there is no available statistical model and therefore no method to estimate losses without additional analysis beyond the scope of this review.

In making the calculations presented here we were constrained to use the CALSIM model output for the various flows by month and year. The concerns expressed in Chapter 5 apply here*: we do not believe that the system will actually be operated to obtain monthly patterns of flow like those in the CALSIM output*. This is particularly true in January and October, when wild swings in flows from one year to the next indicate a situation that would be very unlikely in the real system.

Direct Losses of Delta Smelt

Flows in Old and Middle River are related to salvage of delta smelt and other fish at the south Delta fish facilities. Annual salvage in turn is generally assumed to be a small fraction of entrainment losses, particularly for young (small) fish, because of various other losses attributed to export pumping, including predation in the waterways leading to the facilities and inefficient capture of delta smelt by the facilities.

Here we present estimates of export entrainment losses as a fraction of the population of delta smelt during the adult stage and the larval to early juvenile stage, only a small fraction of which is salvaged (Kimmerer 2008). The calculations were based on results of Kimmerer (2008) as amended for adult delta smelt by Kimmerer (2011). The general procedure was to determine a relationship for each of these two life stages between survival and flow variables that were available from CALSIM. Flows used were Old and Middle River flow (OMR) for adults, and net inflow (i.e., inflow less north Delta diversion flow, NDD) and export flow in the south Delta for larvae and juveniles combined.

We modeled the entire period of CALSIM analysis (WY 1922-2003) for the BDCP scenarios, and the historical period (1955-2003) for comparison. We calculated losses as described in

Appendix C for the BDCP scenarios for both time periods, and for the historical period using Dayflow variables and OMR flows from USGS monitoring.

The principal assumptions were:

- The relationships used to calculate survival or recruitment accurately reflected the corresponding population parameters; that is, the confidence intervals of the predictions were assumed to include the true values of the population parameters with 95% probability. Note that these analyses (Kimmerer 2008, 2011) have not been repeated by any analysts, although Miller (2011) provided a detailed critique. This is rather worrisome, because both the BiOP and several published modeling studies rely on the accuracy of those analyses (Maunder and Deriso 2011, Rose et al. 2013a, b).
- Changes due to BDCP actions were cumulative such that each factor could be examined in isolation from the others, and its effect considered separately from the others.
- The only changes considered were those due to the entrainment effects of flow. Long-term changes in sea level, tidal prism, temperature, salinity, and physical configuration of the Delta were neglected, despite their likely influence on the exposure of the smelt population to export entrainment. Exceptions to this were the influences of these factors on flows modeled by CALSIM.
- The flow time-series produced by CALSIM accurately reflected the influence of the various changes (but note concerns expressed above and in previous chapters).
- The broad spatial distributions of delta smelt will not differ substantially from those existing when the above analyses were made. This may not be true if the fraction of the population in the north Delta is higher now and in the future than when the analyses were made (Miller 2011, Kimmerer 2011).

Losses of adult delta smelt were calculated as a linear function of OMR flows. Annual percent loss under each of the three scenarios was similar for the historical and modeled time periods (Figure 6.1). The estimated proportion of adults lost to entrainment was slightly lower for the NAA than for the historical period, reflecting overall lower export flows presumably because some operating rules were not in force during the historical period. The High- and Low-Outflow scenarios (HOS and LOS) both had proportional losses that were ~ half of those under the NAA, or a net change in loss of about 3%/year.

Losses of larval + juvenile smelt were modeled as a function of exports from the south Delta and inflow to the Delta less diversions from the North Delta facility. The patterns for young smelt were somewhat similar to those for adults but with larger differences among scenarios. The NAA had substantially lower losses than the historical condition over the historical period (Figure 6.2). Flows projected for both the HOS and LOS resulted in much lower losses than for the NAA, with losses under the HOS reduced to ~2%/year on average.

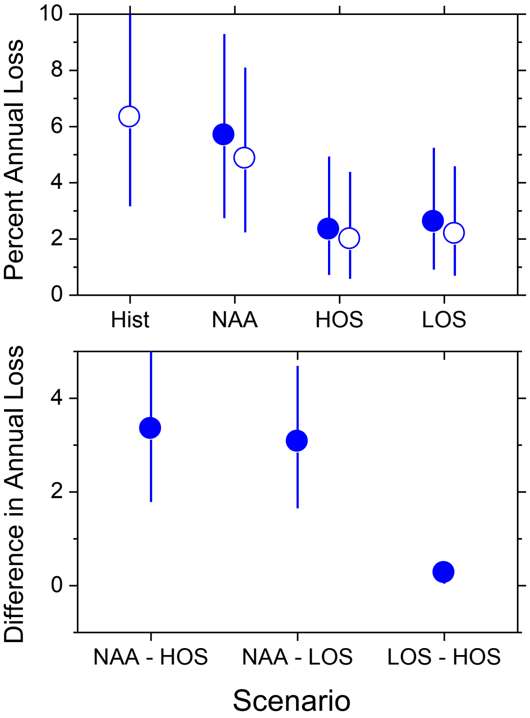

Figure 6.1. Annual percentage of adult delta smelt lost to export pumping for three scenarios and the historical time series. Symbols give means (see text) and error bars give the 95% confidence limit calculated as quantiles of the 1000 simulated samples of the respective distributions. Top panel, percent annual loss for 1922-2003 (filled symbols) and for 1980-2003 (open symbols) including the historical data. Bottom panel, differences between pairs of model scenarios.

We combined results for adults and larvae + juveniles within each calendar year by first calculating the proportion of the population that would remain after 20 years at the mean values in Figures 6.1 and 6.2, then multiplying the proportions remaining to get the influence of these scenarios over both life stages. This is effectively a long-term survival percentage. These are not predictions, and are useful only for examining differences among scenarios. The resulting percentages were 38% for the HOS, 23% for the LOS, and 2% for the NAA (Table 6.1). In other words, the two scenarios with a north Delta diversion resulted in 19- and 11-fold increases in survival over a 20-year period.

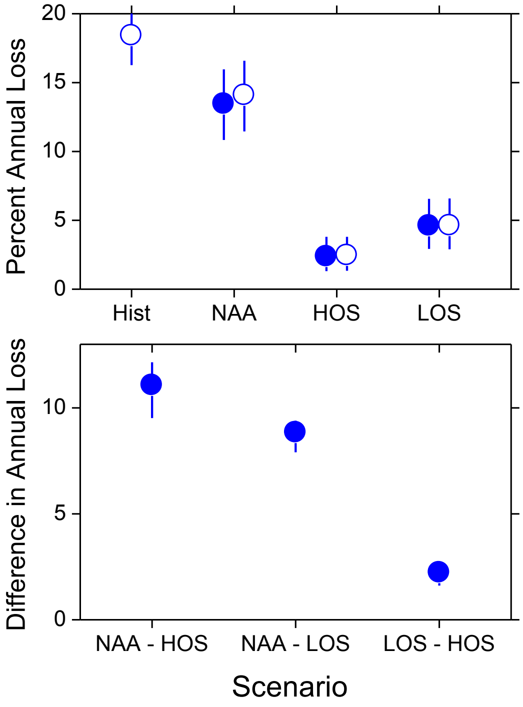

Figure 6.2. As in Figure 6.1 for losses of juvenile delta smelt.

These numbers are highly uncertain, since the value for NAA is so small and variable (Table 6.1). There are indications that losses have been overestimated, especially given the potentially large subpopulation of young delta smelt that may be resident in the Cache Slough complex, where they are immune from effects of export pumping in the south Delta (Miller 2011). Using the upper confidence limits of the projected population size at the end of 20 years (i.e., the lower 95% confidence limits of the loss estimates) the ratios of population remaining after 20 years would have been 14 for HOS and 9 for LOS. These confidence limits do not account for any upward bias in loss estimates, and the loss estimates can and should be refined to reflect current understanding.

Nevertheless, the results of this analysis show a substantial improvement in long-term survival of delta smelt under HOS and to a lesser extent LOS, *provided the water projects are operated in ways that result in flows similar to those in the simulation.* Taken at face value the mean difference in losses between NAA and either of the other scenarios would have roughly sufficed to reverse the decline in delta smelt during the early 2000s.

Table 6.1. Percent of delta smelt population remaining for each of three BDCP scenarios after 20 years of losses at the rates estimated and shown in Figures 1 and 2. Values given with 95% confidence intervals.

	Adults	Juveniles	Combined
NAA	31 ± 22	6 ± 4	2 ± 2
HOS	62 ± 25	62 ± 15	38 ± 19
LOS	59 ± 25	39 ± 15	23 ± 13

Outflow Effects

Two time periods are considered for effects of changed outflow: fall for delta smelt and spring for longfin smelt. These effects are typically cast in terms of X2. For this analysis we calculated X2 from outflow as determined by CALSIM, using the monthly relationship in Jassby et al. (1995), as has been done for all previous analyses of relationships of X2 to abundance indices or habitat of fish (e.g., Feyrer et al. 2007, Kimmerer et al. 2009). CALSIM also produces X2 but it is for the previous month and is somewhat different from that used previously, particularly since it is said to account for sea-level rise and the effects of additional tidal prism due to marsh restoration. Since we were focused on the early long-term (ELT), we elected for now to neglect these considerations and use an X2 value that reflected the anticipated outflows in the same way as in the analyses of X2 effects on fish.

Fall X2 Effects on Delta Smelt

The USFWS Biological Opinion (BiOP) for delta smelt proposes to use X2 in the September-December period as a management tool. The principal basis for this action is the analyses of fall habitat indices (Feyrer et al. 2007, 2011) and an unpublished analysis relating the Summer Townet index to the previous fall Midwater Trawl index and X2:

$$TNS_{y+1} \sim a + bMWT_y + cX2_y + \varepsilon_y \qquad (6.1)$$

where TNS is the summer townet index, MWT the fall midwater trawl index, y is year, ε is error, a, b, and c are fitted parameters, and the time frame was restricted to after 1987 to account for the changes in the foodweb resulting from the introduction of the clam *Potamocorbula amurensis* (See Chapter 7 regarding food limitation of delta smelt).

This model assumes that the main effect of fall X2 on delta smelt is through a combination of survival and growth and therefore population reproduction in the following spring, resulting in effects on abundance in the following summer. Equation 6.1 is somewhat illogical in modeling TNS as an additive function of MWT and X2, and it is also strongly influenced by the data point from 1998, the wettest fall among those included in the analysis. Removing that point weakens that relationship somewhat, although it remains strong. Nevertheless, we fitted an alternative model:

$$\log(TNS_{y+1}) \sim a + b\log(MWT_y) + cX2_y + \varepsilon_y \qquad (6.2)$$

which is more in keeping with the form of the other X2 models (Jassby et al. 1995). This model was fitted to all the data since 1987 using a robust regression method to allow for some over-dispersion in the residuals (function *rlm*, Venables and Ripley 2003). The regression coefficients were a=2.7, b= 0.62 ± 0.22, and c= 0.061 ± 0.55, R^2=0.68, and diagnostic plots revealed that this model was appropriate for the data (Figure 6.3). In particular 1998, and unusually wet year, did not have a strong influence on this relationship.

We extrapolated from this model to the BDCP scenarios using the CALSIM-modeled outflows. The target was the summer townet index, which we examined as a ratio to that predicted under NAA. In contrast to earlier analyses, we did not attempt to relate this to long-term population growth.

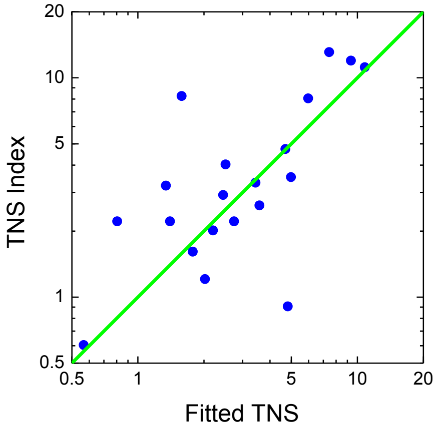

Figure 6.3. Fitted and measured summer townet index (TNS) with a 1:1 line. Values were fitted using Equation 6.2.

The modeled monthly outflow values were converted to X2 according to the monthly equation in Jassby et al. (1995), with the initial value (October 1921) set to the equilibrium X2 for the modeled flow. This was combined with historical monthly mean X2 values and all were averaged over September-December. Equation 6.2 was then used to predict the summer townet index from the mean fall midwater trawl index from 1988 to 2011 and X2 for the three scenarios.

Results showed HOS to have, on average, a slightly higher summer townet index than under NAA (Figure 6.4). The ratio of townet indices determined under HOS to that under NAA was 1.02, i.e., a 2% greater index under HOS, with 10th and 90th percentiles of 0.89 and 1.10 respectively. About a third of the values had lower confidence limits below zero, indicating low confidence that a real increase would be achieved under these conditions.

By contrast, the predicted ratio of townet index for LOS:NAA was about the same as that for HOS:NAA about half of the time, and the other half of the time it was much lower, with large confidence intervals related to the uncertainty in the prediction from the model. The calculated ratio had a median of 0.98 with 10th and 90th percentiles of 0.60 and 1.10. This peculiar pattern arose from the patterns of outflow in the CALSIM output (see Chapter 5). We have very low confidence that these patterns reflect how the system would really be operated, and therefore suggest these results be considered as conditional on proposed operational rules.

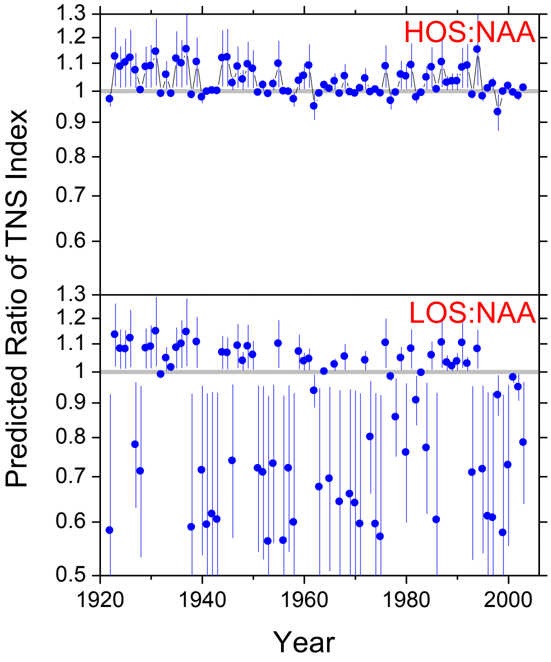

Figure 6.4. Ratios of predicted TNS index by year from HOS (top) and LOS (bottom) to those from NAA.

Spring Outflow/X2 Effects on Longfin Smelt

Longfin smelt has the strongest relationship of abundance index to X2 of any fish (Jassby et al. 1995). The index for a given level of X2 has declined, but the response to flow has not changed. We updated the latest published version of this relationship (Kimmerer et al. 2009) by adding two step changes in time: one in 1987-1988 corresponding to the spread of the clam *Potamocorbula amurensis*, and the other in 2003-2004, the POD decline (Thomson et al. 2010). The statistical model used was

$$\log_{10}(LFS_y) = a_y + bX2_y + \varepsilon_y \qquad 6.3$$

Where LFS is the annual index of longfin smelt abundance from the fall midwater trawl survey, y is year, X2 is monthly values averaged over either January-June (as in Jassby et al. 1995) or March-May, and ε is error. Fitting parameters are *a*, which takes one of three values by year group, and *b*, the slope of the X2 relationship.

The resulting relationship (Figure 6.5) shows both the effect of X2 and the two step-changes in abundance index. Diagnostic statistics showed that the model was appropriate. Since we were interested in the difference between the two alternative flow scenarios and NAA, the only parameter that concerned us here was *b*, which had a value of -0.054 ± 0.005 km^{-1}, essentially identical to previously published values. Averaging X2 over March-May gave a slope of -0.049 ± 0.005 km^{-1}, and the fit was slightly inferior to that of the January-June model.

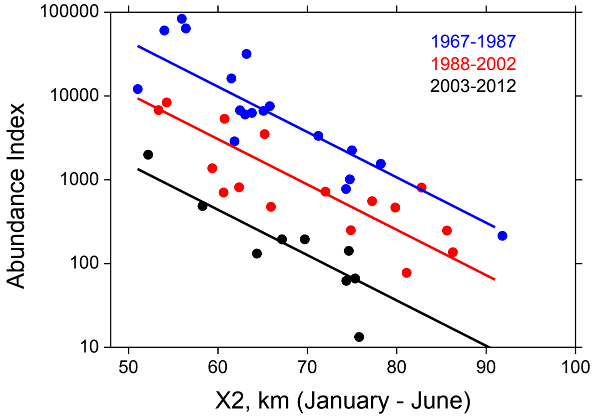

Figure 6.5. Abundance index of longfin smelt vs. X2 averaged over January-June, with step changes between 1987 and 1988 and between 2002 and 2003. Colors of points and lines indicate the time period.

The months selected in the original analysis were based on the assumption that the (unknown) X2 mechanism operated during early life history of longfin smelt, which smelt experts linked to this period. Autocorrelation in the X2 values through months means that statistical analysis provides little guidance for improving the selection of months. A better understanding of the mechanism(s) underlying the relationship would probably allow this period to be narrowed and focused, but for now there is little basis for selecting a narrower period for averaging X2.

The predictions from the above model were then applied to the X2 values calculated from the CALSIM projections of outflow for the 82-year period. We did not attempt to propagate prediction error because it is small compared to variability in outflow. Applying the January-June value for the three selected scenarios resulted in scant differences in predicted abundance indices (Figure 6.6). The median $\log_{10}$ ratio of indices for HOS:NAA was 1.00 (mean 1.05) with 10th and 90th percentiles of 0.91 and 1.27. Corresponding values for LOS:NAA were median 0.92 (mean 0.92) and percentiles of 0.83 and 1.00.

Thus, changes in outflow resulting from the CALSIM projections of spring outflow were small, particularly on the scale of the high variability with X2. HOS provided a minuscule increase in the mean but the median did not change from NAA, indicating that half of the years had higher, and half lower, values under HOS than under NAA. LOS gave values that were ~8% lower than those under NAA.

Although it would be desirable to link such calculations to a population-dynamics model, no such model is available; furthermore, previous analyses have shown that abundance of longfin smelt is highly predictable from X2 and, more recently, groups of years as done above. This does not mean that stock-recruit relationships are unimportant; an alternative analysis models a recruitment index, the log of the ratio of MWT to the MWT value 2 years earlier, as a function of X2 (Nobriga and Rosenfield, in prep.). However, it is unlikely this analysis would indicate a stronger effect of X2 on longfin smelt under BDCP.

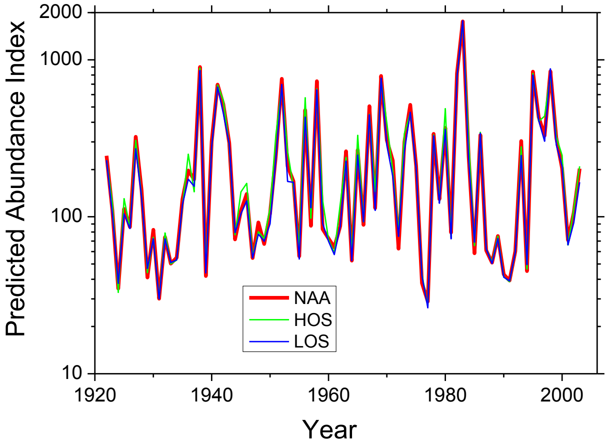

Figure 6.6. Predicted abundance from the model in Figure 6.3 for the three BDCP scenarios. The intercept for the third time period (2003-2012) was used to calculate these indices.

Conclusions

The modeled flow changes under BDCP have mixed effects on the two smelt species. For delta smelt, changes in flow in the south Delta had a marked effect on survival of both adult and young smelt, such that gains of several percent a year would be forecasted for the difference between the NAA and the two with-project alternatives. Effects of outflow on delta smelt were small for HOS compared with NAA, while projections under LOS showed about half the time a marked reduction in predicted summer abundance index compared to NAA. Effects of spring outflow on longfin smelt were not very large.

The results for delta smelt were somewhat surprising, since food supply is clearly an important limitation (Chapter 7) and more likely implicated in the decline than export losses. We nevertheless stand by these results subject to the following contingencies:

- The water projects will be operated to achieve similar flow patterns as in the CALSIM output we used in our analysis.
- Future re-analyses of the influence of export pumping on delta smelt are used to refine these estimates.
- Effects of increasing temperature, introductions of quagga or zebra mussels or other high-impact species, changing flow-X2 relationship, rising sea level, and catastrophic inundation of Delta islands do not materially alter the trajectory of delta smelt.

The last point is presented almost facetiously – things will change, in some ways we can predict and other ways we cannot. The BDCP takes account of some of these changes but others are just as likely over the time frame of the project and should be accounted for

(Chapter 8). Nevertheless, at present we lack the capability to include these factors in a more thorough analysis, but believe it should be done.

Longfin smelt, by contrast, are unlikely to be much affected by BDCP. The anticipated changes in outflow are rather minor, and the flows needed for substantial changes in longfin smelt abundance are likely too great to be practically achieved.

Chapter 7: Likely Response of Listed Fishes to Physical Habitat Restoration

Introduction

This Chapter focuses on the proposed restoration of physical habitat in the Delta and Suisun Marsh. Because of time constraints we have focused on the potential benefits of floodplain and marsh restoration to delta and longfin smelt. These benefits are postulated to occur through expanded physical habitat for the fish, or through export of food from the restored areas to smelt habitat.

Summary of Assessment

The BDCP proposes to restore 55,000 acres of subtidal to intertidal habitat[1] of which 20,600 acres is to be allocated among various Restoration Opportunity Areas (ROAs) in the Delta and Suisun Marsh and the remainder to be allocated later. If completed this restoration will substantially increase the inundated portion of the Plan Area; for example if all 7000 acres assigned to Suisun Marsh were restored it would roughly triple the area exposed to tidal action.

The ROA's include Suisun Marsh, Cache Slough, and the eastern, southern, and western Delta . The documentation is unclear on the depth profiles of these areas and for calculations below we have assumed that about half of each will be intertidal and the remainder subtidal with a mean depth of 2 meters. The document lists the aquatic and terrestrial species expected to benefit from these actions, but here we focus only on their likely effects on the two smelt species.

Our results to date lead to the following preliminary conclusions:

- Delta and longfin smelt are usually food-limited, meaning that population levels would rise if there were more zooplankton in their rearing areas. This limitation is probably stronger in spring-fall than in winter.
- The BDCP is overly optimistic about the likely benefits of tidal marsh restoration to the smelt species, particularly the extent of food production.
- A review of the literature suggests that tidal marshes may either import or export phytoplankton and zooplankton.
- Under highly favorable assumptions about production and export of plankton, restored tidal marshes could make at most a modest contribution to extant plankton production.

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[1] "Habitat" means the location and conditions in which a population of a species lives; here we follow the BDCP document in using the term to mean a physical space. We likewise use "restore" to mean to prepare that space for the potential occupation of one or more species, irrespective of the previous condition of the space.

- The subpopulation of delta smelt that inhabit the Cache Slough complex through summer may benefit from additional physical space in that area. The same could be true in Suisun Marsh although current use by smelts is low.
- The high level of uncertainty about outcomes points to the use of moderate- to large-scale experimental restoration projects to determine whether the proposed restoration will achieve the food-production goals and, if so, how to design them optimally.

Marsh Restoration

Review of conceptual basis

The BDCP anticipates many benefits to delta and longfin smelt. Although the documentation is unclear on the expected magnitudes of these benefits, it is uniformly optimistic that they will contribute substantially to recovery of the species. Here we focus on two potential benefits to the smelts from the restoration of tidal habitats. First, the restored habitats are expected to provide a food supply that will enhance the food supply available to the smelts. Second, the restored habitats are expected to provide additional physical space, resulting in an increase in smelt abundance. Neither of these proposed benefits is well developed in the documentation, and the literature cited seems to have been selected to support the claims made. The BDCP documentation furthermore contains factual errors and misinterpretations that cast doubt upon the projections that are made, however qualitative. We therefore conducted a reasonably thorough analysis of these specific claims, within the constraints of time available.

The first outcome requires two conditions: 1) that the smelt populations are currently food-limited, meaning that an increase in concentration of food organisms would result in a higher abundance of smelt; and 2) that the restored marshes will produce and export enough food organisms to make a difference to the population status of the smelts.

BDCP Appendix 5E uses “prod-acres” to index the expected productivity of phytoplankton in the restored areas. However, this index is conceptually flawed in two ways. First, it uses an estimate of growth rate rather than production of phytoplankton, which is the product of growth rate and biomass. Second, it assumes implicitly that all phytoplankton growth is available as food for the zooplankton consumed by the smelt species, but analyses published on the San Francisco Estuary and elsewhere show that most of the production is consumed by benthos and by microzooplankton such as ciliates (e.g., Lopez et al. 2006, Lucas and Thompson 2012, Kimmerer and Thompson submitted).

The smelt species are expected to occupy some of the restored habitats. This may provide benefits in the form of increased opportunities for individual fish to find suitable conditions such as spawning substrate, food patches, or shelter from predators. A potential benefit is to diversify the locations in which the smelt species occur, in an attempt to increase resilience of the populations to local perturbations such as high-temperature periods or toxic spills.

Analysis of components

For effects of food production and export we assessed the evidence for food limitation of the smelt populations, and for the amount of food (zooplankton) that restored marshes would export to waters where the smelt species occur. For physical habitat we examined current patterns of occurrence to determine the likely effect of additional physical habitat on the smelt species.

We do not address other potential indirect impacts of marsh restoration, or interactions with other proposed projects. Restoration of extensive areas of marsh will increase the tidal prism in the restored area. This will affect tidal currents and elevations both locally and all the way to Carquinez Strait, and therefore affect salinity penetration and the movement of sediments. The effects on salinity have been included in the modeling presented in BDCP documents, but we did not review this. The U.S. Army Corps of Engineers has proposed a project, now on hold, to deepen the Sacramento Deep-Water Ship Channel, which is currently an important part of the habitat of delta smelt. This and other non-BDCP projects should be taken into account when considering impacts of BDCP.

Are smelt species food-limited?

What is the evidence for and against food limitation in delta and longfin smelt? By food limitation we mean a situation in which an increase in concentration of food organisms would result in a higher abundance of smelt. This does not require that all or even most fish have depressed growth or reproductive rates, only that at least some of them do. Substantial food limitation would require the following to be true:

1. The density of food organisms is too low to support the maximum growth rate of the fish.
2. Therefore some fish are in poorer condition or grow more slowly than under food satiation.
3. Either or both of the following:
    a. Survival over a life stage depends on condition and therefore food supply
    b. Reproductive rate of an adult varies with growth rate during development through its effect on maturity or total eggs per female.
4. Higher reproduction leads to a larger population, all else being equal. We assume this condition must be true as a straightforward consequence of population dynamics.

Food limitation could occur at one or more life stages, which may occupy different parts of the estuary. During spawning and early life delta smelt are mostly in freshwater. During the late larval stage (~July) until the pre-spawning migration in December, part of the population is in the low-salinity zone (LSZ, salinity ~0.5-5), and part is in the Cache Slough-Liberty Island complex in the North Delta (Sommer et al. 2011). Longfin smelt also spawn in freshwater but move earlier and further seaward (Rosenfield and Baxter 2007, Kimmerer et al. 2009). We refer to fish between metamorphosis from the larval stage to their spawning migration as juveniles (i.e., including all fish caught in the fall midwater trawl survey). Both smelt species consume available plankton in their habitat, with the size of prey related to that of the fish.

Food limitation is surprisingly difficult to demonstrate in a fish population. Nearly all populations must be food limited to some degree. However, food limitation of individual fish can be difficult to detect. The prey and the fish are spatially patchy and temporally variable, so the degree of food limitation is sporadic and patchy. Great differences among individuals in feeding success result in differences in growth and survival, such that the survivors are those that have been well fed. Feeding success also interacts with other influences such as predation risk and physiological stress.

The analysis of food limitation relies on a variety of direct and indirect evidence (Details in Appendix D). Some studies suggest food limitation inferred from correlations of abundance or length with measures of food availability, indices of gut fullness and physiological condition of field-caught smelt, and laboratory-derived estimates of feeding rate in relation to food concentration. A few other studies do not support food limitation in these species. However, the weight of evidence suggests that food is limiting the populations of both smelt species.

Export of food from shallow restored areas

One purported benefit to smelts of restored shallow areas is that elevated food production in these areas will be exported as a subsidy to open waters where the smelts are abundant. The implicit conceptual model is that these shallow areas will produce an excess of phytoplankton and zooplankton that will then be exported by stream flow or tidal currents. A subsidy of phytoplankton could stimulate zooplankton production in the open waters, since the zooplankton in this estuary are chronically food-limited in their growth or reproduction (Müller-Solger et al. 2002, Kimmerer et al. 2005). However, grazing by clams is likely to prevent such a subsidy from having much effect on zooplankton production. The alternative subsidy is that of zooplankton grown within the restored areas, including larger forms such as mysids that are consumed by juvenile longfin smelt and adult delta smelt.

The magnitude of any subsidy depends also on the transport process. Where the transport is mediated by tidally-driven currents, the subsidy will be related to the tidal exchange and the difference in biomass between the restored area and the open water. Where it is mediated by river flow, the subsidy will depend on the net flow and the biomass in the restored area.

Here we examine the literature on subsidies from marshes, use a simple model to estimate the magnitude of such a subsidy of either phytoplankton or zooplankton, and estimate the proportional flux from the Suisun Marsh to Suisun Bay using output from a particle-tracking model as a measure of the extant subsidy. Our conclusions are:

- The literature does not support a confident assertion that marshes will subsidize zooplankton of the open waters.
- Calculated subsidies of phytoplankton and zooplankton are modest under optimistic assumptions about in-marsh production and design of restoration sites.

- A subsidy of zooplankton from Suisun Marsh to Grizzly Bay cannot be very large under current conditions, and is unlikely to be much larger with the proposed extent of restoration.

Do shallow areas export phytoplankton or zooplankton?

Marshes can be major producers of organic matter because of their extensive vegetated surface exposed to sunlight, shallow waters leading to light penetration through all or most of the water column, and the continual supply of nutrients from the open waters and from land (Figure 7.1). This appears to be true even for recently restored marshes (Howe and Simenstad 2011). Over the long term, mass must balance, so production in excess of respiration by organisms within the marsh must be either buried or exported as organic matter or organisms to adjacent estuarine waters.

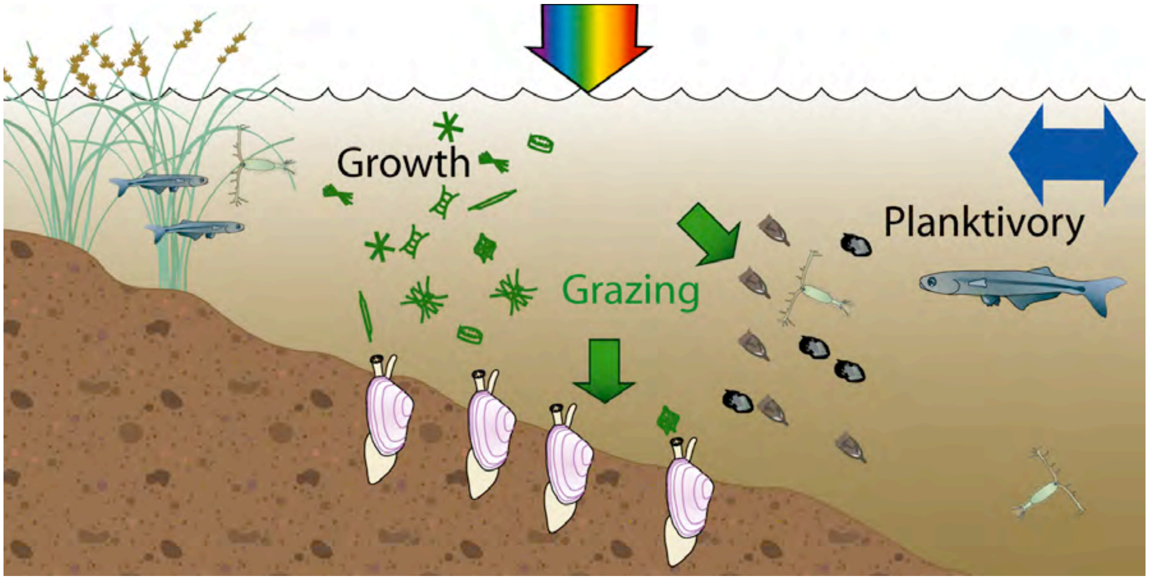

Figure 7.1. Conceptual model of the production of food for pelagic fish in a low-order tidal marsh channel. Because the water is shallow (and may be clearer than in adjacent channels) light penetration is good and growth of phytoplankton and benthic microalgae is high. Losses of phytoplankton occur through benthic grazing and by pelagic grazing, chiefly by microzooplankton but also by larger zooplankton such as copepods that can be consumed by fish. Benthic grazers filter a certain volume of water every day, so the shallower the water the more intensive the grazing on the plankton of the marsh. Small planktivorous fish such as Mississippi silversides seek shelter in the shallowest and vegetated areas; thus consumption of zooplankton is also more focused and more selective for larger organisms in shallow water. Tidal exchange of water with the adjacent higher-order (larger) channel transports nutrients, organic matter, and plankton between marsh and channel, but the direction of transport for zooplankton may be in or out of the marsh depending on the outcomes of the various production and consumption processes.

Export of organic matter from marshes to adjacent estuarine waters was first considered as the "outwelling hypothesis" (Odum 1980, Nixon 1980). This hypothesis holds that the export of labile organic matter provides an important subsidy to nourish adjacent waters of the estuary or continental shelf.

The outwelling hypothesis originated in studies of extensive, rich marshes on the east and Gulf coasts, but even there, quantitative demonstrations of its importance to estuarine or coastal foodwebs were few (Dame et al. 1986). Much of the difficulty arises from the technical challenge of measuring a small net flux in a large tidal signal with high variability (Dame et al. 1986). In addition, dissolved and particulate organic matter produced by rooted vegetation can be highly refractory and therefore largely unavailable to estuarine pelagic foodwebs, which are usually fueled mainly by phytoplankton (Sobczak et al. 2002, 2005).

Marshes can be sites of high productivity by benthic or planktonic microalgae because they are shallow, so waters are well-lit. Therefore a marsh could export organic matter as living phytoplankton. However, the extent of this export depends on consumption within the marsh, including consumption of phytoplankton by benthic grazers in shallow waters, as illustrated for flooded islands in the Delta by Lopez et al. (2006). Often overlooked in attempts at a mass-balance of phytoplankton is the high rate of consumption by microzooplankton, which typically consume about 60% of the production by phytoplankton in estuaries (Calbet and Landry 2004, York et al. 2011). Thus, the production actually available for consumption by mesozooplankton, and for export, is considerably lower than would be expected from estimates of primary production.

For zooplankton the magnitude and direction of the flux depends on behavior and on size- and taxon-specific patterns of mortality. In particular, visual predation by fish can exert strong control on the size distributions, and therefore species distributions, of zooplankton (Brooks and Dodson 1965). Vertical movements of zooplankton and hatching or settlement of larvae can lead to spatial patterns of abundance that do not reflect tidal transport (Houser and Allen 1996). Consumption of zooplankton by small fish that seek food and shelter in shallow areas can reduce zooplankton abundance near shore, and shift the size distribution toward smaller forms, in lakes (Brucet et al. 2005, 2010), lagoons (Badosa et al. 2007), and marshes (Cooper et al. 2012). The outcome can be net fluxes into shallow areas (Carlson 1978, Kimmerer and McKinnon 1989), and marshes can be simultaneously sinks for copepods and areas of aggregation for bottom-oriented larvae (Mazumder et al. 2009).

Thus, marshes may act either as net sources or sinks for plankton in the adjacent waters, depending on the availability of habitat for small fish and the degree of colonization by benthic grazers such as clams. The exact details of the exchange processes depend on the physical configuration of the marsh including permanence of inundation (Brucet et al. 2005), residence time of the water (Lucas and Thompson 2012), and the biological composition, i.e., the kinds and abundance of producers and consumers within the marsh including transient organisms (Kneib 1997). If the excess organic matter is being transported by fish as in some east coast marshes (Kneib 1997), little benefit would accrue to planktivorous fish in the open waters such as the smelts.

Few of these aspects have been examined in marshes of the San Francisco Estuary. Long-term studies of Suisun Marsh have revealed a lot about fish assemblages (e.g., Matern et al. 2002, Feyrer et al. 2003) and medusae and some zooplankton (Wintzer et al. 2011, Meek et al. 2013), and some detailed studies of exchange processes have been undertaken (Culberson et al.2004). Zooplankton abundance is highest in small sloughs of long residence time (P. Moyle, UC Davis, personal communication).

Foodwebs in diverse marshes of the San Francisco Estuary are supported more by local plant production than by estuarine phytoplankton (Howe and Simenstad 2007, 2011). This implies a division of organic-matter sources between those supporting littoral and marsh foodwebs and those supporting pelagic foodwebs (Grimaldo et al. 2009).

Lehman et al. (2010) estimated the fluxes of various substances in and out of Liberty Island, a flooded island in the Cache Slough complex in the northern Delta. They found large seasonal shifts in the magnitude and direction of fluxes. In particular, seasonal chlorophyll flux was into Liberty Island in spring and out in fall, based on point measurements, and into the island in all seasons but more so in spring and summer, based on the continuous measurements. Fluxes of copepods were out during spring and fall, and in during summer, based on a total of six sampling days. Although Lehman et al. (2010) linked fluxes into Liberty Island with storage within the island, it was equally likely to have been a function of consumption, particularly since high inward fluxes of chlorophyll and zooplankton occurred in summer when biological activity would have been high.

A few other marshes and restoration sites in the estuary have been investigated for their potential links to open waters. The South Bay Salt Ponds, which began to be reconnected to the tidal action of the Bay in 2006, are highly productive and may export organic matter to nearby estuarine waters (Thebault et al. 2008). A marsh at China Camp in San Pablo Bay was a net sink for mysids, probably through predation within the marsh (Dean et al. 2005).

Calculated subsidies

Here we assume that the restored areas will actually produce an excess of phytoplankton or zooplankton over adjacent waters, and ask what additional level of food availability to the smelt would result. This is based on a very simple model using data from IEP monitoring, described in detail in Appendix E (See Figure 7.2). The basis of this model is to calculate the subsidy based on high levels of biomass and growth rate in a 2500-acre marsh that is closely connected to smelt habitat and has an optimum rate of exchange with the open water. We assume smelt habitat is represented by the Low-Salinity Zone (LSZ), which has a volume of about 0.5 km^3.

A subsidy is maximized by a large marsh close to the smelt habitat, with tidal exchange close to but not above the net population growth rate of the plankton (Figure 7.3). The subsidy is degraded or even reversed by consumption (clams, planktivorous fish) within the marsh. Water depth may have a positive or negative effect on the subsidy.

The simple model in Appendix E shows that under an extremely favorable set of conditions both within and outside of the marsh, a modest subsidy of phytoplankton is possible.

Phytoplankton input to the LSZ could amount to 16%/day, or about half of the daily net production in the LSZ. However, smelt species do not eat phytoplankton, and the conversion of phytoplankton to zooplankton depends on factors in the open water such as grazing. The direct subsidy of zooplankton would be about 3%/day, also under unrealistically ideal conditions. Although this is not negligible, any reduction in this value would effectively eliminate the subsidy to open water.

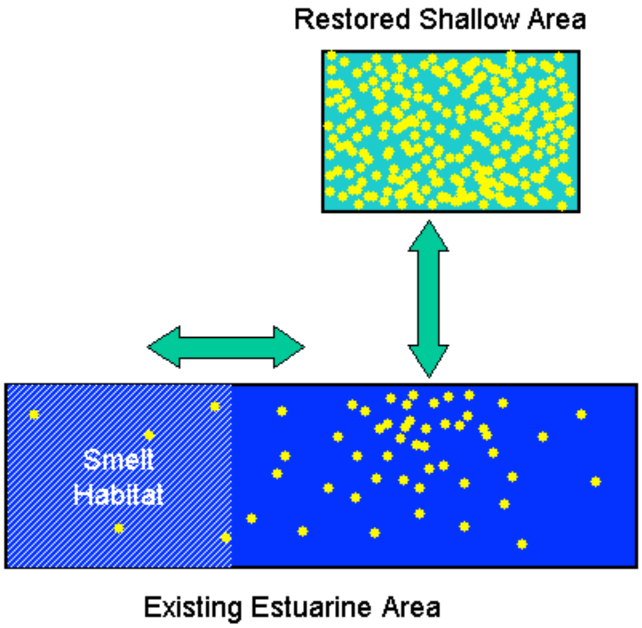

Figure 7.2. Schematic diagram of a subsidy of zooplankton (yellow circles) from a restored tidal marsh or other shallow area to an existing estuarine area. Zooplankton move by dispersion (double-sided arrows) between the restored and existing areas, and within the existing area from the outlet of the restored area to other regions of the estuary including smelt habitat. Advection may alter the flow of zooplankton, for example, if the restored area is on a creek that produces a net flow into the existing area.

Zooplankton export from Suisun Marsh

One of the proposed restoration areas is in the northern end of Suisun Marsh. We estimated the subsidy of copepods to the LSZ from this region using IEP monitoring data and using a particle-tracking model to estimate exchange rate (Appendix E). If the copepods behaved as passive particles, this subsidy would amount to about 2%/d of the population in the LSZ. This is unlikely to produce a noticeable increase in copepod biomass, as their potential population growth rates are on the order of 10%/d. However, particles that migrate to the bottom tidally or remain near the bottom, as most zooplankton do in the estuary (Kimmerer et al. 2002), were essentially trapped within the northern marsh. Behavioral responses to tidal currents, consumption within the marsh, the distance from the mouth of the marsh to the habitat of the smelts, and the operations of the salinity control gate on Montezuma Slough would all reduce or even eliminate this subsidy.

The real world

Several features of the actual restoration site would alter the subsidy to open waters from the analyses above. First, the enlarged restoration area will alter the tidal prism and therefore the exchange rate. The proposed restoration for Suisun Marsh would increase the inundated area 2-3-fold, with a corresponding increase in tidal currents. Since most of the exchange will be mediated by tides, this could substantially increase the exchange rate. Whether this would increase or decrease the subsidy would depend on the net population growth rate achieved in the marsh in relation to the exchange rate. Resolving the change in residence time would require a 3D model with very accurate bathymetry throughout the region. It is impossible to tell with available information whether the stronger tidal connections would result in a greater subsidy from Suisun Marsh, or whether this would be offset by zooplankton behavior or by consumption within the marsh. Such calculations could be done using a hydrodynamic and particle tracking model and some reasonable assumptions about zooplankton behavior.

The BDCP documents acknowledge (but then mostly ignore) that grazing by clams that settle in or near restored subtidal areas may remove all or most of the phytoplankton production and some of the zooplankton. Grazing by clams and zooplankton (including microzooplankton) removed all of the phytoplankton production in the LSZ nearly all the time from late spring through fall during 1988 – 2008 (Kimmerer and Thompson submitted.). Whether clams settle in the newly restored areas is critical in determining whether the area can export any phytoplankton (Lucas and Thompson 2012). At present clams are not abundant in Suisun Marsh except for the larger Suisun and Montezuma Sloughs, where they probably remove a substantial fraction of the phytoplankton and small zooplankton that would otherwise enter Grizzly Bay.

Zooplankton organisms are not passive, and undergo tidal migrations in Suisun Bay (Kimmerer et al. 1998, 2002). It is very likely that they will do so also in marsh channels, which would greatly lengthen the residence time for copepods produced in the marsh, particularly in the far northern area of Suisun Marsh. In addition, several studies have shown that zooplankton organisms may also be consumed by various planktivorous fish within a marsh, resulting in a net flux of zooplankton into the marsh (see literature review above).

Finally, some of the proposed restoration sites are far from the centers of distribution of delta and longfin smelt. Travel times from these sites to where the fish are may be on the order of weeks to months in the dry season or when the North Delta diversions are operating (Kimmerer and Nobriga 2008). A plankton population can double or halve its biomass in a few days depending on local food supply and predation. Thus, any export of zooplankton from a restored area should be assumed to subsidize only the local area.

All of these considerations are based on rather crude models of exchange and population processes. That is appropriate given the level of specificity of the BDCP design.

Nevertheless, this analysis raises significant questions about the putative subsidy from restored areas to estuarine foodwebs. To address this uncertainty, long before any actual restoration takes place a program of analysis, modeling, and experimental restoration should be undertaken.

Likely use of restored areas

Like other fish, smelt use a variety of habitats and appear to explore their environment to find suitable places for spawning, growth, and development. As pelagic fish, their principal habitat is open waters of the estuary, either in freshwater during the larval to early juvenile stages in spring to early summer, or in the low-salinity zone until winter. The low-salinity zone during summer-fall is generally in the western Delta and Suisun Bay, including the channels of Suisun Marsh. Delta smelt appear to be surface-oriented, which would allow them access to shallow areas (Aasen 1999).

The fundamental problem for both smelt species in the open-water, brackish regions of the estuary is the low food supply (discussed above) and possibly also the decreasing turbidity (Kimmerer 2004). Those trends may be difficult to reverse, spelling trouble ahead for the smelts. However, in recent years some proportion of the delta smelt population has remained in freshwater in the Cache Slough complex, despite high temperature there (Sommer and Mejia 2013). This may provide an alternative habitat in which the smelt population can either avoid poor conditions in the LSZ, or hedge its bets on future conditions. Longfin smelt are apparently not very abundant in Cache Slough.

Delta and longfin smelt have been collected in the Suisun Marsh fish survey (Matern et al. 2002). Delta smelt are not common in Suisun Marsh during summer-fall but were formerly common in winter to early spring (Matern et al. 2002) when the fish are migrating and spawning. About 0.7% of 3291 otter trawl samples from the Suisun Marsh survey during May-October of 1982 – 2009 and about 3% of 3320 samples during November – April contained delta smelt, mostly maturing juveniles and adults. The low catches in summer were not due to small size of the fish, since young-of-the-year longfin smelt of the same size range were captured frequently in that program. Temperature in the larger sloughs is ~1°C higher than in Grizzly Bay in July and August, based on IEP and UC Davis monitoring data, but if smelt avoid the warmer water in summer it does not explain the low catches for all of May-October. Longfin smelt are much more abundant in the Suisun Marsh channels than delta smelt, occurring in 8% of samples in May-October and 12% of samples in November-April with no obvious differences among the various sloughs.

The 20mm survey catches smelts during spring-summer in Montezuma Slough in Suisun Marsh and in central Suisun Bay including one station in Grizzly Bay near the major western entrance to the marsh. A graphical comparison of catch per trawl in these locations did not reveal a consistent difference for either species. A similar comparison of catch per trawl between Montezuma Slough and Grizzly Bay in the Fall Midwater Trawl survey also did not reveal a consistent difference, except that delta smelt were somewhat less abundant in the slough than in Grizzly Bay during September. Thus, it appears delta and longfin smelt are roughly as abundant in the larger sloughs of Suisun Marsh as in the open water of the estuary.

The key question for this aspect of restoration is whether additional physical habitat would result in larger populations of smelt. Abundance of delta smelt is related to an index of habitat availability based on salinity and turbidity (Feyrer et al. 2007, 2011, Nobriga et al. 2008). However, the size of the LSZ (volume or area) does not seem to be strongly related to the abundance of either smelt species (Kimmerer et al. 2009, in press). This may be because the LSZ is a contiguous stretch of water whose physical features are ephemeral, and the fish can move around readily within that region. In contrast, shallow tidal areas may offer enough physical structure to provide a wealth of sub-habitats with variable conditions. In that case, having more habitat area could lead to a greater abundance of fish. Note that a relationship between the quantity of habitat and the size of a fish population need not rely on a density-dependent relationship between habitat and the survival or reproduction of individual fish, which seems unlikely for delta smelt at current population levels.

Thus, we are cautiously optimistic that restoration of habitat may result in colonization and subsequent population expansion of delta smelt in the Cache Slough area including the Sacramento Ship Channel (Moyle 2008, Sommer and Mejia 2013). Longfin smelt seem unlikely to benefit from this. We cannot determine whether either species would benefit from similar restoration in the Suisun Marsh or the western Delta. The other restoration sites are too remote from the current population centers to offer much reason for optimism about their colonization by either smelt species.

Floodplain

The BDCP proposes to alter the Fremont Weir at the upstream end of the Yolo Bypass so that the Bypass would flood at lower stages of the Sacramento River. We consider here only the likely effects on the smelt species.

Review of conceptual basis

Although the smelt species do not use floodplain as habitat, elevated production of plankton on the floodplain may provide a subsidy to smelt habitat. This situation differs slightly from that of the potential subsidy from marshes discussed above. First, the floodplain is a flow-through system so that increased biomass of plankton will be transported by the mean, river-derived flow rather than by tidal flow. Second, residence time on a floodplain varies with flow conditions, from hours to a few days under high-flow conditions to effectively infinite in ponds remaining after the floodplain stops draining.

Analysis of components

Apart from its suitability as habitat for fish and other species, the Yolo Bypass may also support foodwebs within the estuary. The mechanism for this would be higher phytoplankton and zooplankton production because of shallow depth and better light penetration than in river channels, as well as higher temperature (Lehman et al. 2007). Whether this translates to zooplankton is uncertain; zooplankton abundance on the Bypass was similar to that in the Sacramento River during 1998-2001 (Sommer et al. 2004). Plankton biomass on a floodplain may increase late in the season as residence time increases and fish switch to larger prey (Grozholz and Gallo 2006), but that was not observed on the Yolo Bypass in most years (Sommer et al. 2004).

At very high flows residence time on the Bypass is probably too short to allow for a buildup of biomass, while at lower flows such a buildup may occur but the rate of export may be low (Schemel et al. 2004). This implies that, as with tidal exchange in marshes (Figure 7.3), there is an intermediate range of flow that maximizes export of plankton.

A subsidy from the Yolo Bypass may be more or less direct to delta smelt habitat, notably in the Cache Slough complex at the southern end of the Bypass. In addition, it may subsidize the low-salinity habitat used by both smelt species in late spring through fall.

In Appendix F we examine the evidence for a subsidy of zooplankton to the open water of the estuary under the current configuration using existing zooplankton data. We do not actually calculate the magnitude of the subsidy, since several factors would intervene to alter conditions. In particular, the Bypass could be flooded later in the year than is now the case, and the greater light penetration and higher temperature would provide for greater plankton production than now occurs. Furthermore, Bypass flow would represent a greater proportion of total inflow to the Delta later in the year, resulting in less dilution of the plankton coming off the Bypass.

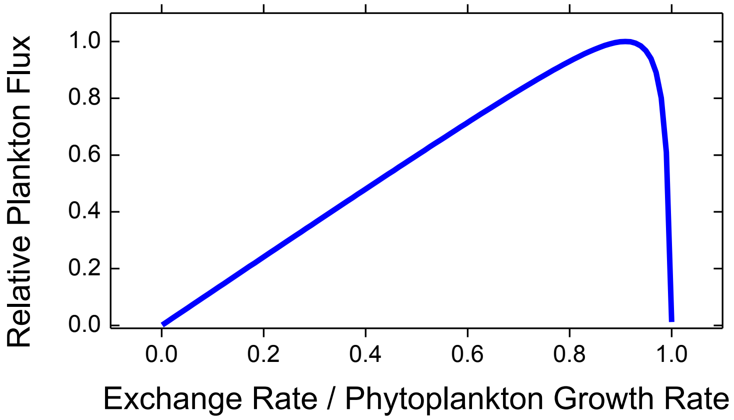

Figure 7.3. Relative magnitude of phytoplankton flux from a tidal marsh as a function of exchange rate, scaled to the growth rate of the phytoplankton. The model is based on a balance among import of nutrients to the marsh, uptake of nutrients to support growth of phytoplankton, and export of phytoplankton. All nutrient uptake is by phytoplankton, there is no consumption, and the phytoplankton concentration in the receiving water is zero.

Our analysis shows no evidence that the open waters of the estuary receive a detectable subsidy of phytoplankton or zooplankton. If anything, plankton abundance is inversely related to Yolo Bypass flow, either during the month of sampling between flow during the winter and zooplankton abundance in the following summer.

Conclusions

There are many reasons for restoring physical habitat in the Delta and Suisun Marsh, and a host of species that are likely to benefit. Among the listed fish species, young salmon use marsh and floodplain during residence, salutatory downstream movement, and active migration. However, it is unclear whether conditions in the Delta have a substantial role in the population dynamics of salmon, and therefore we have elected to focus on the smelt species, for which the Delta is a key part of home (Sommer and Mejia 2013).

The BDCP is overly optimistic about the potential benefits to delta and longfin smelt of physical habitat restoration. Longfin smelt do not appear to use marshes as habitat to any great extent. Delta smelt are also considered pelagic but their persistent abundance in the Cache Slough complex, and greater abundance in shallow rather than deep water, suggests some potential benefit to their population of expanded marsh in that area. The magnitude of this benefit is impossible to predict, as is the degree to which marsh and floodplain restoration might cause an increase, or reverse the decline, in the delta smelt population. Under these conditions it is premature to assert that the restoration activity will have such an effect, until studies including pilot projects and even some smaller full-scale restoration projects can show whether an effect is to be expected.

The idea that restored marsh and floodplain will export substantial amounts of zooplankton to the open waters of the estuary is not tenable. The ecology of shallow waters suggests that shallow areas are more likely to be sinks for zooplankton. Even if they were sources, simple mass-balance considerations indicate that the resulting export would produce at most a small enhancement of extant zooplankton of the open waters. This idea should be dropped from discussions of BDCP, although experimental work should press ahead to determine under what conditions marsh habitats could be sources of significant food for delta and longfin smelt in the open waters.

Chapter 8: Regulatory Oversight and Assurances

Introduction

The previous chapters have demonstrated the relatively high uncertainties associated with proposed conservation actions in BDCP. These uncertainties will likely result in the need to change Plan goals and objectives in the future, along with the prescribed conservation measures to address them.

This chapter addresses the question whether the draft Bay Delta Conservation Plan includes governance policies that are "transparent and resilient to political and special interest influence." We divide our analysis into two parts: (1) analysis of the regulatory oversight of plan implementation and adaptive management; and (2) evaluation of the regulatory assurances and proposed 50-year "no surprises" guarantee.

Regulatory Oversight

Introduction

The draft BDCP vests primary responsibility for implementing the Plan in a Program Manager, who shall "ensure that the BDCP is properly implemented throughout the duration of the Plan" (BDCP 7-2). The Program Manager's authority is broad and includes protection and restoration of habitat, reduction of ecological stressors, management of conserved habitat, coordinated operation of the CVP and SWP, and development of the new facilities authorized by the Plan (BDCP 7-3).[1]

The Program Manager's implementation of the BDCP is subject to oversight by the Authorized Entity Group, which will be comprised of the Director of the California Department of Water Resources as operator of the SWP, the Regional Director of the U.S. Bureau of Reclamation as operator of the CVP, and one representative each of the CVP and SWP contractors if the contractors are issued permits under the Plan (BDCP 7-8).[2] The BDCP also covers certain diversions of water that are not part of CVP or SWP operations and recognizes that these water supply operators may seek incidental take permits under the terms and conditions of the BDCP. If this occurs, these water projects would become Authorized Entities, but would not be members of the Authorized Entity Group (BDCP 7-8).

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[1] The Program Manager also will have responsibility over the Implementation Office, which will assist the Program Manager in all aspects of implementation of the Plan, BDCP 7-4 to 7-5, and the Science Manager and Adaptive Management Team as described in Chapter 9 of this report.

[2] A question has arisen whether the fish and wildlife agencies legally may grant incidental take permits to the CVP and SWP contractors under the federal Endangered Species Act and the California Natural Community Conservation Planning Act. We address this question in the Appendix G.

The Authorized Entity Group's authority over the BDCP also is broad and multifaceted. The draft BDCP states:

> The Authorized Entity Group will provide oversight and direction to the Program Manager on matters concerning the implementation of the BDCP, provide input and guidance on general policy and program-related matters, monitor and assess the effectiveness of the Implementation Office in implementing the Plan, and foster and maintain collaborative and constructive relationships with the State and federal fish and wildlife agencies, other public agencies, stakeholders and other interested parties, and local government throughout the implementation of the BDCP (BDCP 7-8 to 7-9).

This oversight structure means that the Authorized Entity Group will exercise significant authority over both the coordinated operation of the CVP and SWP and implementation of the BDCP itself. Indeed, the draft Plan declares that the Program Manager "will report to the Authorized Entity Group, and act in accordance with the group's direction" (BDCP 7-2).

The draft Plan vests regulatory responsibility within the BDCP in a "Permit Oversight Group," which is composed of the Regional Director of the U.S. Fish and Wildlife Service, the Regional Administrator of the National Marine Fisheries Service, and the Director of the California Department of Fish and Wildlife (BDCP 7-11). It then states that the three agencies "are expected to issue regulatory authorizations to the Authorized Entities" pursuant to the federal Endangered Species Act and the California Natural Community Conservation Act (BDCP 7-11).

The draft Plan also provides that, "[c]onsistent with their authorities under these laws, the fish and wildlife agencies will retain responsibility for monitoring compliance with the BDCP, approving certain implementation actions, and enforcing the provisions of their respective regulatory authorizations" (BDCP 7-11). This means that, although the USFWS, NMFS, and CDFW will work together as members of the Permit Oversight Group for the purpose of supervising implementation of the BDCP, each agency will retain its independent regulatory powers over the CVP, SWP, and other water users under the federal and state Endangered Species Acts.[3]

This structure is consonant with both the Endangered Species Acts and the California Natural Community Conservation Planning Act, because it separates the regulatory oversight responsibilities of the federal and state fish and wildlife agencies from the operational responsibilities of the Program Manager and the Authorized Entity Group. This structural delineation is undermined, however, by the draft Plan's more detailed definition of the "function" of the Permit Oversight Group, which blurs the distinction between implementation and regulation. It also is undermined by provisions in the draft Plan that grant the Authorized Entity

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[3] This independent regulatory authority is subject, however, to an important caveat—the draft Plan's requirement of consistency between future section 7 consultations and the BDCP—as described below. *See* pp. 7-8 to 7-9.

Group—rather than the regulatory agencies—veto authority over changes to the conservation measures, biological objectives, and adaptive management strategies, as well as over amendments to the BDCP itself.

Regulatory vs. Programmatic Responsibilities: Implementation

The draft Plan grants the Permit Oversight Group a significant role in implementing the conservation goals and adaptive management strategies of the BDCP:

> The Permit Oversight Group will be involved in certain decisions relating to the implementation of water operations and other conservation measures, actions proposed through the adaptive management program or in response to changed circumstances, approaches to monitoring and scientific research (BDCP 7-11).

It then provides that the Permit Oversight Group "will have the following roles, among others, in implementation matters":

- *Approve, jointly with the Authorized Entity Group,* changes to conservation measures or biological objectives proposed by the Adaptive Management Team.
- *Decide, jointly with the Authorized Entity Group,* all other adaptive management matters for which concurrence has not been reached by the Adaptive Management Team.
- Provide input into the selection of the Program Manager and the Science Manager.
- *Provide input and concur* with the consistency of specified sections of the Annual Work Plan and Budget with the BDCP and with certain agency decisions.
- *Provide input and concur* with the consistency of the Annual Delta Water Operations Plan with the BDCP.
- Provide input and accept Annual Reports.
- *Provide input and approve* plan amendments[4] (BDCP 7-11 to 7-12: emphasis added).

These definitions are poorly drafted, and they assign programmatic authority to the fish and wildlife agencies that may undermine their regulatory responsibilities. We therefore recommend that the draft BDCP be revised in two ways:

First, where the parties to the negotiations want to grant the Permit Oversight Group authority to determine whether certain actions or documents are consistent with the BDCP, the Plan should define its responsibilities more clearly and precisely than does the current language—*e.g.,* "provide input and concur"; "provide input

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[4] The draft Plan also contains a placeholder "function," which states that the Permit Oversight Group also may play a role in "decision-making regarding real-time operations, consistent with the criteria of *CM1 Water Facilities and Operation* and other limitations set out in the BDCP and annual Delta water operations plans." As the details of this role as still under negotiation, we do not address it here except to note that the role of the Permit Oversight Group should be clearly defined and limited to regulatory oversight as explained in the text.

and accept"; and "provide input and approve." Thus, the draft Plan should be revised to state:

> The Permit Oversight Group shall have exclusive authority to determine whether the Annual Work Plan Budget and Annual Delta Operations Plan are consistent with the BDCP. If the Permit Oversight Group does not issue a determination of consistency, the document in question shall be revised and resubmitted to the Permit Oversight Group for approval or further remission and revision.

Second, the Permit Oversight Group's role should be limited to regulatory oversight. The "functions" listed in the draft Plan conflate the Permit Oversight Group's regulatory responsibilities with the programmatic implementation duties that are best left with the Program Manager and the Authorized Entities Group. Although there is some practical value in collaboration among the regulators and the regulated—*e.g.,* having the fish and wildlife agencies give their "input" during the drafting of annual operations plans—it is better policy to maintain the exclusive regulatory role of the Permit Oversight Group. A regulatory agency that has a stake in the creation of the program and policy decisions that it must ultimately review will not be able to bring its independent judgment to bear in evaluating those same decisions for consistency with the Plan and other applicable laws.

The conflation of regulatory and programmatic responsibilities is especially dangerous in the case of revisions to the biological objectives, conservation measures, and other adaptive management strategies. As currently written, the draft Plan grants the Authorized Entity Group an effective veto over proposed changes to the these programs, even if the Adaptive Management Team, the Science Manager, the Program Manager, and the Permit Oversight Group have concluded that changes are needed to ensure programmatic compliance with the BDCP or to fulfill the requirements of the federal and state Endangered Species Acts (BDCP 7-11).

A better course would be to revise the draft Plan to allow the Science Manager and Adaptive Management Team—subject to oversight and approval from the Program Manager and Authorized Entity Group—to make revisions to the biological objectives, conservation measures, and other adaptive management strategies. These changes then would be submitted to the Permit Oversight Group for review and approval or remission. The Permit Oversight Group also should have independent authority to revise the biological objectives, conservation measures, and other adaptive management strategies if it concludes that the existing programs are inadequate to comply with the BDCP or other governing law.

Regulatory vs. Programmatic Responsibilities: Policy Modifications and Amendments to the BDCP

A similar problem exists for modifications to the BDCP itself. The draft Plan recognizes that "Plan modifications may be needed periodically to clarify provisions or correct unanticipated inconsistencies in the documents" (BDCP 6-45). It then identifies three types of plan modifications: administrative changes, minor modifications, and formal amendments. Only the latter two concern us here.

The draft Plan defines "minor modifications" as including transfers of acreage between Restoration Opportunity Areas or conservation zones and "[a]djustments of conservation measures or biological objectives . . . consistent with the monitoring and adaptive management program and intended to enhance benefits to covered species" (BDCP 6-46). It then describes "formal amendments" as including, but not limited to:

- Changes to the geographic boundary of the BDCP.
- Additions of species to the covered species list.
- Increases in the allowable take limits of covered activities or the addition of new covered activities to the Plan.
- Substantial changes in implementation schedules that will have significant adverse effects on the covered species.
- Changes in water operations beyond those described under *CM1 Water Facilities and Operations*. (BDCP 6-47).

The "minor modifications" and "formal amendments" thus include all aspects of BDCP implementation that will be vital to the success or failure of the BDCP. Yet, the draft Plan expressly provides that the Authorized Entities may veto any such changes.[5] For minor modifications, the draft BDCP states: "If any Authorized Entity disagrees with the proposed minor modification or revision for any reason, the minor modification or revision will not be incorporated into the BDCP" (BDCP 6-46).[6] The draft Plan similarly declares that formal amendments "will be subject to review and approval by the Implementation Office and the Authorized Entities."[7]

The BDCP is fundamentally a set of terms and conditions that allow the principal regulatory agencies—the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Wildlife—to authorize the construction and operation of physical improvements to the Delta that will facilitate more reliable (and, one may hope, more environmentally sustainable)

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[5] Please note that the draft BDCP states that the Authorized Entities—not the Authorized Entity Group—hold this veto power. This may be a typographical error, as the Authorized Entities are not granted implementation decisionmaking authority (except through the Authorized Entity Group) any other place in the document. If it the BDCP negotiators in fact intend to vest veto authority in the Authorized Entities, however, this is especially problematic as the Authorized Entities potentially include water users other than those that comprise the Authorized Entity Group. BDCP 7-8.

[6] By contrast, if any of the fish and wildlife regulatory agencies disagrees with a proposed minor modification, its rights are limited to insisting that the proposal be treated as a formal amendment to the Plan. BDCP 6-46.

[7] At least in the case of formal amendments the draft Plan recognizes a relative parity in the rights of the regulators and the regulated, acknowledging that such amendments "will require corresponding amendment to the authorizations/ permits, in accordance with applicable laws and regulations regarding permit amendments." BDCP 6-47. It also states, however, that the "fish and wildlife agencies will use reasonable efforts to process proposed amendments within 180 days." BDCP 6-46.

exports of water by the CVP and SWP. Although the motivating purpose of the BDCP is to facilitate this water development, the regulatory agencies' foundational responsibility is to ensure that the project does not jeopardize the continued existence of the species that are listed for protection under the federal and state Endangered Species Acts.

To accomplish this essential obligation, the fish and wildlife agencies must both insist on an initial set of biological objectives, conservation measures, and conditions on coordinated project operations that will fulfill this purpose; *and* they must have the means of ensuring that the implementation of the BDCP will continue to achieve that goal throughout its fifty year term.

We do not believe that the draft Plan satisfies this second requirement, as it vests veto authority over necessary changes in the biological objectives, conservation measures, adaptive management strategies, and the terms and conditions of the BDCP itself, not in the regulatory agencies, but in the regulated entities that comprise the Authorized Entity Group. We therefore recommend revision of the draft Plan to require that all "minor modifications" and "formal amendments" to the BDCP be subject to review and approval by the Permit Oversight Group.

As explained above, we also recommend that the draft Plan be revised to authorize the Permit Oversight Group itself to initiate and make changes to the biological objectives, conservation measures, and other adaptive management strategies that the fish and wildlife agencies conclude are needed to ensure the protection and recovery of the species listed under the federal and state Endangered Species Acts. This unilateral authority must extend to all of the identified "minor modifications" and to at least one of the defined "formal amendments"—*viz.* "substantial changes in implementation schedules that will have significant adverse effects on the covered species" (BDCP 6-47).[8]

The other listed "formal amendments"—which include alteration of the geographic boundaries of the Plan and the addition of new species and covered activities—are different, as they include possible changes to the scope and structure of the BDCP, rather than adaptive changes to the implementation and achievement of the goals of the existing BDCP. The draft Plan therefore properly states that formal amendments

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[8] The governance structure set forth in the current draft Plan also may jeopardize the likelihood that the BDCP will be incorporated into the Delta Plan. *See* California Water Code § 85320-85322. The Delta Reform Act provides:

> The BDCP shall include a transparent, real-time operational decisionmaking process in which *fishery agencies ensure that applicable biological performance measures are achieved in a timely manner with respect to water system operations.* [*Id.* § 85321 (emphasis added).]

The Authorized Entity Group's veto authority over changes to the biological objectives, conservation measures, and adaptive management strategies means that the fish and wildlife agencies would not have the power to ensure that the biological measures will be achieved. The draft Plan therefore violates this statutory mandate, and the CDFW and the Delta Stewardship Council consequently would likely be precluded from incorporating the BDCP into the Delta Plan.

"will involve the same process that was required for the original approval of the BDCP"--i.e., approval of both the Authorized Entities and the Permit Oversight Group (BDCP 6-47).[9]

Regulatory Assurances and the "No Surprises" Policy

Introduction

The draft Plan proposes to create two types of "regulatory assurances." First, it seeks to eliminate the uncertainties associated with consultation under section 7 of the federal Endangered Species Act for coordinated CVP and SWP operations by stipulating that future biological opinions shall be consistent with the terms and conditions of the BDCP. Second, it offers "no surprises" guarantees both for deviations between the biological opinions and the BDCP and for future changes to the BDCP itself. In addition, the draft Plan places difficult scientific, legal, and political burdens on the state and federal governments' power to terminate the incidental take permits and to rescind the BDCP.

In our judgment, these regulatory assurances compound the risks described in the preceding section because they severely constrain the fish and wildlife agencies' ability to respond to inadequacies in the biological objectives, conservation measures, and other adaptive management strategies—even apart from the veto authority that the draft Plan vests in the Authorized Entity Group.

Section 7 Consultation and the BDCP

According to the draft Plan, once the facilities authorized by the BDCP are constructed, the Plan will largely displace the existing section 7 consultation requirements applicable to coordinated CVP and SWP operations: "On the basis of the BDCP and the companion biological assessment, it is expected that USFWS and NMFS will issue a new joint biological opinion (BiOp) that would supersede BiOps existing at that time as they relate to SWP and CVP actions addressed by the BDCP" (BDCP 4-2). The draft Plan then requires that the new biological opinion (as well as any subsequent biological opinions issued during the 50-year term of the BDCP) be consistent with the terms and conditions of the BDCP itself:

> The BDCP is intended to meet the requirements of the ESA and provide the basis for regulatory coverage for a range of activities identified in the Plan. . . .

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[9] The draft Plan also provides that, "[i]n most cases, an amendment will require public review and comment, CEQA and NEPA compliance, and intra-Service Section 7 consultation," and it requires the fish and wildlife agencies to use "reasonable efforts to process proposed amendments within 180 days." BDCP 6-47. 180 days is probably insufficient time, however, to allow for section 7 consultation, internal agency analysis of the effects of proposed formal amendments on listed species and their habitat, and the drafting, public review, and completion of a new or supplemental EIS/EIR.

It is also worth noting that even this limited "bilateral" approval process for structural amendments to the BDCP may not be consistent with federal law. The ESA rules provide that all incidental take permits "are issued subject to the condition that the National Marine Fisheries Service reserves the right to amend the provisions of a permit for just cause at any time during its term." 50 C.F.R. § 222.306(c).

> Unless otherwise required by law or regulation, in any Section 7 consultation related to a covered activity or associated federal action and covered species, USFWS and NMFS will each ensure that the resulting BiOps are consistent with the integrated BiOp for the BDCP (BDCP 6-44).

We do not necessarily object to this consistency directive. An important goal of the BDCP is to provide all parties—especially the Authorized Entities—with a measure of regulatory and operational certainty that will enable them both to invest in the new facilities and to make water management decisions in their respective service areas in reliance on water deliveries from the CVP and SWP. To the extent that future section 7 consultations conform to the terms of the BDCP, that certainty is enhanced. We also note the first clause of the second sentence quoted above, which expressly reserves the authority of USFWS and NMFS to issue biological opinions that depart from the terms of the BDCP if necessary to comply with the governing law. This law, of course, includes section 7(a)(2) of the federal ESA, which requires all consulting agencies to ensure that their actions are "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat." 16 U.S.C. § 1536(a)(2).

We do believe, however, that the proposal to substitute the BDCP for section 7 consultation as the principal means of applying the federal Endangered Species Act to the CVP, SWP, and other Authorized Entities reinforces our recommendations from the preceding section—*viz.* that the Permit Oversight Group must maintain the independent regulatory prerogatives that the fish and wildlife agencies currently possess and must have authority to approve or to deny proposed changes in the biological objectives, conservation measures, and other terms and conditions of the BDCP as required to protect and recover the species covered by the Plan. Our support for the biological opinion/BDCP consistency directive should be read with this caveat.

"No Surprises"

The draft Plan contains two "no surprises" guarantees. The first applies to changes in coordinated CVP and SWP operations or water supply capabilities that may be required by future biological opinions that do not conform to the BDCP. The second is a more general "no surprises" commitment that protects the Authorized Entities from certain changes to the BDCP itself[10].

According to the draft Plan, "Ecological conditions in the Delta are likely to change as a result of future events and circumstances that may occur during the course of the implementation of the BDCP" (BDCP 6-30). The draft then lists seven "Changed Circumstances Related to the BDCP"—levee failures, flooding, new species listings, wildfire, toxic or hazardous spills, nonnative invasive species, and climate change (BDCP 6-31). For each of these "reasonably foreseeable" changes, the draft Plan describes the "planned responses" that BDCP administrators will undertake (BDCP

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[10] As noted in chapter 2, USBR is not covered by the "no surprises" assurance. BDCP 6-29.

6-31 to 6-42).[11] The draft Plan states that the responses "have been designed to be practical and roughly proportional to the impacts of covered activities on covered species and natural communities, yet sufficient to effectively address such events" (BDCP 6-30). The BDCP budget will include funds to cover the costs of implementing some of the planned responses to "reasonably foreseeable" changed circumstances (BDCP 6-30).[12]

The draft Plan also recognizes that "unforeseen circumstances" may require changes to the biological objectives, conservation measures, adaptive management strategies, or the terms and conditions of the BDCP itself. It defines unforeseen circumstances as "changes in circumstances that affect a species or geographic area covered by an HCP that could not reasonably have been anticipated by the plan participants during the development of the conservation plan, and that result in a substantial and adverse change in the status of a covered species" (BDCP 6-42 citing 50 C.F.R. § 17.3 & 50 C.F.R. § 222.102). The draft Plan contains a similar definition of "unforeseen circumstances" under state law. These are "changes affecting one or more species, habitat, natural community, or the geographic area covered by a conservation plan that could not reasonably have been anticipated at the time of plan development, and that result in a substantial adverse change in the status of one or more covered species" (BDCP 6-43 citing California Fish & Game Code § 2805(k)).

The draft Plan then sets forth the following regulatory assurances under federal and state law:

> Under ESA regulations, if unforeseen circumstances arise during the life of the BDCP, USFWS and/or NMFS may not require the commitment of additional land or financial compensation, or additional restrictions on the use of land, water, or other natural resources other than those agreed to in the plan, unless the Authorized Entities consent (BDCP 6-42).

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[11] The Implementation Office is charged with identifying the onset of a changed circumstance, working with the Permit Oversight Group to fashion a response, and for implementing and monitoring the responsive actions (BDCP 6-31).

[12] This funding process is described in Chapter 8 of the draft BDCP. *See* BDCP 8-60 to 8-64. The draft states generally that, to "allow for the ability to respond to changed circumstances should they occur, the Implementation Office should maintain a reserve fund for covering costs of changed circumstances" (BDCP 8-61). The draft Plan explains that this is because "the risk of some changed circumstances—*e.g.,* failure of levees attached to tidal marsh and floodplain restoration—and cost of remedial measures increases as greater portions of the conservation strategy are implemented." *Id.*

The draft BDCP only includes levee failure and wildfire damage to preserved lands as possible "changed circumstances for which responses are expected to result in additional implementation costs." *Id.* It omits "changed circumstances related to climate change, flooding, failure of water operations infrastructure, nonnative invasive species, new species listings, and toxic or hazardous spills," explaining that the response costs for these are accounted for in the initial BDCP funding, will be paid by the state and federal governments under the "no surprises" guarantees, or would be the responsibility of a third party. BDCP 8-61 to 8-62.

> In the event of unforeseen circumstances, CDFW will not require additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources without the consent of the plan participants for a period of time specified in the Implementation Agreement (BDCP 6-43).[13]

As noted above, for federal agencies that are subject to section 7 consultation (including consultation for coordinated CVP/SWP operations), the draft Plan contains an additional "no surprises" pledge if new biological opinions contain operational or water supply restrictions that differ from those set forth in the BDCP:

> Furthermore, USFWS and NMFS will not require additional land, water, or other natural resources, or financial compensation or additional restrictions on the use of land, water, or other natural resources regarding the implementation of covered activities beyond the measures provided for under the BDCP, the Implementing Agreement, the incidental take permits, and the integrated BiOp (BDCP 6-44).

The purpose of these regulatory assurances is to exempt the Authorized Entities from any of the costs of complying with the federal and state Endangered Species Acts except as defined in (and funded pursuant to) the terms of the BDCP. These "no surprises" guarantees therefore may place the financial burden of some future changes to the BDCP and project operations exclusively on state and federal taxpayers.

Although both federal Endangered Species Act regulations and the California Natural Community Conservation Planning Act authorize "no surprises" guarantees, we believe, given the uncertainties outlined in the previous chapters, that there is a significant risk that the costs of compensating the projects and their contractors for future "unforeseen" hydrologic, engineering, and operational changes will be excessive. More importantly, we are concerned that the state and federal governments' assumption of liability may deter the fish and wildlife agencies from making changes to future biological opinions or to the BDCP itself that the agencies believe are necessary to protect and recover listed species. The following example focusing on the "reasonably foreseeable" changed circumstance of climate change illustrates our concerns.

The draft Plan defines climate change as "[l]ong-term changes in sea level, watershed hydrology, precipitation, temperature (air or water), or ocean conditions that are of the magnitude or effect assumed for the effects analysis and that adversely affect conservation strategy implementation or covered species are considered a changed circumstance" (BDCP 6-41). It then provides that the

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[13] The draft Plan notes that, under California law, "such assurances are not applicable in those circumstances in which CDFW determines that the plan is not being implemented in a manner consistent with the substantive terms of the Implementation Agreement." BDCP 6-43 (citing California Fish & Game Code § 2820(f)(2)).

"occurrence of this changed circumstance will be determined jointly by the Implementation Office and fish and wildlife agencies" (BDCP 6-41).[14]

According to the draft Plan, however, alterations in the ecosystem and threats to listed species caused by climate change will not trigger any management or regulatory responses beyond those set forth in the BDCP. "Because the BDCP already anticipates the effects of climate change, no additional actions will be required to remediate climate change effects on covered species and natural communities in the reserve system" (BDCP 6-41). Rather, the Adaptive Management Team will monitor these changes and the Implementation Office will "continually adjust conservation measures to the changing conditions in the Plan Area as part of the adaptive management program" (BDCP 6-42).

The draft Plan also states that all responses to climate change "will be made as part of the adaptive management and monitoring program. Measures beyond those contemplated by the adaptive management and monitoring program are not likely to be necessary because the conservation strategy was designed to anticipate a reasonable worst-case scenario of climate change. *A change in conservation measures in response to climate change beyond that considered in Chapter 3,* Conservation Strategy, *and through the adaptive management and monitoring program is considered an unforeseen circumstance.*" (BDCP 6-42: emphasis added).

There are two serious problems with this changed circumstances strategy:

First, although the "biological goals and objectives [of the BDCP] have been established at the landscape level to take climate change into account during conservation strategy implementation," and the "conservation strategy, monitoring and research program, and adaptive management and monitoring program already include responses to anticipate climate change effects at the landscape, natural community, and species scales" (BDCP 6-42), the draft Plan correctly anticipates that the biological objectives, conservation measures, and other adaptive management strategies are likely to be modified over time as required to respond to the changed conditions brought about by climate change. Yet, as described previously, all such modifications are subject to approval by the Authorized Entities (BDCP 6-46). The fish and wildlife agencies consequently lack independent authority to determine the appropriate policy and management responses to climate change, even within the confines of the defined responses set forth in Chapter 3 of the BDCP.

Second, changes in conservation measures that differ from the defined responses are "unforeseen circumstances," which trigger the "no surprises" guarantee. Again, while the draft Plan anticipates a broad array of ecological changes likely to be caused by climate change, and lays out a detailed set of programmatic responses, it is folly to believe that the BDCP scientists and negotiators have correctly identified

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[14] We reiterate here the problems that we identified in the preceding section: conflation of the fish and wildlife agencies' regulatory and programmatic roles and the granting of an effective veto to the regulated entities through the Implementation Office.

all of the hydrologic changes, biotic responses, and risks to the ecosystem that will in fact occur over time. As one recent interdisciplinary study of California water policy emphasized:

> New approaches to ecosystem management under changing conditions will require continued, large-scale experimentation aided by computer modeling. This task is complex, because experiments, especially on a large scale, often yield ambiguous results. Also, as with hydrology, the past is not always a good predictor of the future with many ecosystems. Linking human and natural systems, combined with changes in climate and influxes of alien species, creates novel, dynamic ecosystems with no historical analog. Thus, efforts to restore ecosystem functions and attributes involve hitting a moving, only partially visible target. Finally, ecosystem changes are often nonlinear and interrelated. Declines in habitat quality or abundance reduce ecosystem resiliency, with the result that even small changes in conditions can lead to abrupt system collapse and reorganization to a new state. Such thresholds or tipping points are difficult to predict. *Taken together, these factors suggest that efforts to improve conditions for California's native aquatic species will necessarily involve trial and error, and that success is far from guaranteed.*
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> The difficulty is compounded by the high uncertainty of success for specific actions, given ecosystem complexity, gaps in knowledge of how to manipulate many key processes, and, most important, continuing change in climate, invasive species, and other conditions in California. *As a result, a flow regime or water quality target that seems adequate today may not provide the same services in 20 to 30 years. Aiming at a moving target in semi-darkness means that there will be many misses.* (From: Hanak et al., 2011: emphasis added).

The potential consequences of the "no surprises" guarantee in this context are troubling. Fisheries biologists generally agree that diminished seasonal outflow and warming water temperatures place several listed species at risk of extinction (see Cloern et al., 2011; Moyle et al., 2013). The projects that would be authorized by the BDCP should reduce some of the sources of stress on these species by reducing entrainment and predation and by creating substitute habitat, but they will not address several other important stressors such as diminished summer and fall outflow and rising water temperatures. Therefore, sometime during the 50-year term of the BDCP, it may be necessary to construct additional upriver storage (*e.g.,* by increasing the capacity of Shasta Reservoir) to enable more sustained cold-water releases to protect salmon spawning and out-migration.

Yet, under the draft Plan, this action would constitute an "unforeseen circumstance," because it falls outside the defined responses to climate change set forth in the BDCP. The consequence would be that the state and federal taxpayers would have to bear all of the costs of constructing and operating the new or expanded storage, even though the fish and wildlife agencies determined that this action is needed to protect one or more listed species from extinction (while maintaining reservoir releases and exports at the levels and timing authorized by the BDCP).

Alternatively, if funding were not available to construct the new storage capacity, and the fish and wildlife agencies made jeopardy findings and issued new biological opinions that altered reservoir release requirements in a manner that reduced water supply or export capacity, the state and federal governments would have to compensate the Authorized Entities for the value of the lost water or the cost of replacement supplies.[15]

For these reasons, we do not believe that the 50-year "no surprises" guarantees are wise or prudent policy. We understand that the Authorized Entities seek to protect their capital investment and obtain maximum security of their water service capabilities, and that a relatively fixed set of biological objectives, conservation measures, and operational constraints help to achieve these goals (BDCP 1-26). But a 50-year commitment is ill-advised in an ecosystem as complex, variable, and scientifically inscrutable as the Delta. As our colleague Peter Moyle has observed, in the Delta Ecosystem, "[o]ver-negotiation of details in advance is unlikely to enable adequate responsiveness and flexibility" and "even the most well-informed, scientifically based management will encounter surprises and make mistakes" (From Moyle et al., 2012).

The parties to the BDCP negotiations therefore should consider separate "no surprises" guarantees—one governing construction of the BDCP projects, and a series of operational "no surprises" commitments that would be reevaluated every

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[15] During the July 23, 2013, meeting with DWR Director Mark Cowin and CDFW Director Chuck Bonham, Director Cowin stated that it was not the parties' intent to apply the "no surprises" policy to actions taken outside the plan area that may be required to address the effects of climate warming or other changed conditions on listed species. Although we were pleased to learn this, we retain the concerns described in the text for two reasons: First, the draft Plan does not state that new infrastructure or operational changes needed to ensure the survival of species covered by the BDCP are exempt from the "no surprises" guarantee if they are located outside the plan area. Rather, the draft links CVP and SWP facilities and water supply operations upstream of the plan area to the conservation measures that may be required to protect covered species and their downstream habitat (BDCP 1-20). Without an explicit limitation on the "no surprises" guarantee to new, "unforeseen" conservation measures undertaken within the plan area, we believe that there is an unacceptable risk that the Authorized Entities could raise a plausible claim that the "no surprises" policy exempts them from liability for new facilities and operational changes upstream of the plan area that are needed to protect covered species within the plan area.

Second, the draft Plan expressly extends the "no surprises" assurance for future section 7 consultations over new facilities and other changes in CVP operations that are outside the plan area and not part of the BDCP covered activities. The draft Plan stipulates that "USFWS and NMFS will further ensure that the terms of any BiOp issued in connection with projects that are independent of the covered activities and associated federal actions do not create or result in any additional obligation, cost, or expense to the Authorized Entities" (BDCP 6-44).

If the parties to the BDCP negotiations do not intend for the "no surprises" guarantee to cover new construction and project operational changes outside the plan area, then they should revise the draft Plan to say so explicitly and clearly. We also recommend that the sentence quoted above, which exempts the Authorized Entities from all costs associated with section 7 consultations to project facilities and operations other than BDCP covered activities be deleted.

ten years based on *current* information on the appropriateness of the biological objectives, the success or failure of the conservation measures, species survival and recovery, overall ecosystem health, climate change, invasive species, discharges, the effects of authorized project operations, other stressors, and regulatory compliance.

We have chosen ten years for the recommended length of renewable "no surprises" assurances because a ten-year period is likely to include a variety of different types of water years and thus will be sufficiently lengthy to enable BDCP managers and regulators to evaluate how well the biological objectives and conservation measures perform across a spectrum of hydrologic conditions. At the same time, ten years is short enough to minimize the risk that the terms and conditions of the BDCP become antiquated and ineffective in light of the inevitable and unpredictable changes to the ecosystem. Indeed, a series of renewable ten-year "no surprises" guarantees could create a constructive incentive for the parties to the BDCP to monitor progress and achievement of the biological objectives and conservation measures and to make adaptive management changes as required to sustain and recover the covered species and their habitat.[16]

Revocation of Incidental Take Permits and the BDCP

Many of our concerns about the rigidities of the draft Plan and the scope and length of the regulatory assurances would be lessened if there were an effective means of revoking the incidental take permits and thus rescinding the BDCP. But there is not.

As described in the draft Plan, the "Permit Revocation Rule," adopted in 2004, allows the federal fish and wildlife agencies "to nullify regulatory assurances granted under the No Surprises rule and revoke the Section 10 permit only in specified instances, including where continuation of a permitted activity would jeopardize the continued existence of a species covered by an HCP and the impact of the permitted activity on the species has not been remedied in a timely manner" (BDCP 6-48: quoting 69 Fed. Reg. 7172 (Dec. 10, 2004)). The draft Plan states,

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[16] There is nothing in federal or state law that requires that the term of a "no surprises" guarantee be coextensive with the term of the HCP/NCCP. Indeed, the California Natural Communities Conservation Planning Act requires that the duration of all regulatory assurances be based on a careful assessment of the limits of scientific understanding of the covered species and their habitat. California Fish & Game Code § 2820(f) states that the CDFW's "determination of the level of assurances and the time limits specified in the implementation agreement for assurances may be based on localized conditions and shall consider":

> (A) The level of knowledge of the status of the covered species and natural communities.
>
> (B) The adequacy of analysis of the impact of take on covered species.
>
> (C) The use of the best available science to make assessments about the impacts of take, the reliability of mitigation strategies, and the appropriateness of monitoring techniques.
>
> (D) The appropriateness of the size and duration of the plan with respect to quality and amount of data.
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> * * *
>
> (H) The size and duration of the plan.

however, that the "USFWS or NMFS will begin the revocation process only if it is determined that the continuation of a covered activity will appreciably reduce the likelihood of survival and recovery of one or more covered species and that no remedy [other than revocation] can be found and implemented" (BDCP 6-49).

Similarly, under the California Natural Communities Conservation Planning Act, the Department of Fish and Wildlife may revoke the state incidental take permit "if necessary to avoid jeopardizing the continued existence of a listed species" (BDCP 6-49: citing California Fish & Game Code § 2820(c)).[17] The federal and state fish and wildlife agencies also may revoke the permits if the Authorized Entities fail to fulfill their obligations under the BDCP, but only following the dispute resolution process set forth in the Implementing Agreement and "providing the Implementation Office and Authorized Entities with a reasonable opportunity to take appropriate responsive action" (BDCP 6-49).

Before the fish and wildlife agencies may revoke the incidental permits, they must follow a variety of procedures and substantive standards. These include determining, in concert with the Implementation Office, "whether changes can be made to the conservation strategy to remedy the situation" and whether "there are additional voluntary implementation actions that the Authorized Entities could undertake to remedy the situation."

More importantly, the draft Plan also requires the federal fish and wildlife agencies to determine whether they or some other agencies can take actions to ensure the survival of the listed species, rather than imposing such burdens on the parties to the Authorized Entities:

> The USFWS or NMFS will determine whether the fish and wildlife agencies or other state and federal agencies can undertake actions that will remedy the situation. The determination must be based on a thorough review of best available practices considering species population status and the effects of multiple federal and nonfederal actions. *It is recognized that the fish and wildlife agencies have available a wide array of authorities and resources that can be used to provide additional protection for the species, as do other state and federal agencies* (BDCP 6-48 & 6-50: emphasis added).

The draft Plan thus makes it difficult for the fish and wildlife agencies to revoke the incidental take permits if the biological objectives, conservation measures, and adaptive management changes do not achieve their primary goal of protecting and recovering the listed species. Procedural and substantive rigor is not in and of itself

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[17] Section 2820(c) actually addresses a more limited violation of the terms of an NCCP, providing for suspension or revocation if a plan participant fails to "maintain the proportionality between take and conservation measures specified in the implementation agreement and does not either cure the default within 45 days or enter into an agreement with the department within 45 days to expeditiously cure the default." California Fish & Game Code § 2820(c). The more general revocation standard is set forth in section 2820(b)(3)(A)-(D) of the Act.

reason to doubt this last line of defense against extinction. But two additional facts lead us to the conclusion that permit revocation is not likely to be a credible means of ensuring the survival of the species if the BDCP fails its most essential task.

First, neither the federal fish and wildlife agencies nor the California Department of Fish and Wildlife have ever revoked an incidental take permit. Indeed, there is only one case in which a federal incidental take permit has been suspended, and that was for the permittee's violation of the terms and conditions of the habitat conservation plan, rather than because of changes in ecological conditions or the permittee's failure to agree to amendments to the biological objectives and conservation measures[18]. Revocation of the incidental take permits covered by the BCDP therefore would be an unprecedented event.

Second, a decision to revoke the incidental take permits would not be simply a scientific determination that the BDCP—as written today and implemented at some future date during its 50-year existence—is not adequate to ensure the conservation and recovery of the listed species. Although the BDCP assigns the authority to revoke the state incidental take permit to the Director of the California Department of Fish and Wildlife (BDCP 6-50), it stipulates that "[a]ny decision to revoke one or both federal permits must be in writing and must be signed by the Secretary of the Interior or the Secretary of Commerce, as the case may warrant" (BDCP 6-49).[19] In our judgment, this poses an undue risk that the revocation decision would be based on science *and* political considerations. Indeed, there would seem to be no other purpose for elevating the revocation authority from the fish and wildlife agencies to the two Cabinet-level Secretaries.

For these reasons, we do not believe that the state and federal authority to revoke the incidental take permits compensates for the deficiencies in the draft BDCP described above.

Conclusion

We conclude that governance structure set forth in the draft BDCP is neither "transparent [nor] resilient to political and special interest influence." The draft undermines the authority of the federal and state fish and wildlife agencies both by assigning them program responsibilities and by granting the Authorized Entities veto power over changes to the biological objectives, conservation measures, and adaptive management strategies that may be needed to ensure that the Plan achieves its stated goals. To address this deficiency, we recommend that the BDCP be revised to remove the Permit Oversight Group from program decisionmaking and to clarify the regulatory authority of the fish and wildlife agencies both within the BDCP and in their independent roles as principal regulators under the federal and

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[18] *See* U.S. Fish and Wildlife Service Letter to Victor Gonzales, President of WindMar Renewable Energy, Feb. 2, 2012 (decision of partial suspension of incidental take permit).

[19] This would change the process for permit revocation set forth in the federal ESA rules, which vest revocation authority in the Director of the U.S. Fish and Wildlife Service. 50 C.F.R. § 17.22(b)(7).

state Endangered Species Acts and the California Natural Community Conservation Planning Act.

We also believe that the regulatory assurances contained in the draft Plan jeopardize the ability of the fish and wildlife agencies to respond to changed conditions that may require future revisions to the biological objectives and conservation measures of the BDCP. The “no surprises” guarantees—by which the state and federal governments would assume the financial costs of new infrastructure and regulatory changes in CVP/SWP operations needed to address the effects changed circumstances not provided for in the BDCP—are especially troubling. To address this problem, we recommend that the proposed 50-year “no surprises” guarantees be converted into a series of renewable guarantees—the first to cover construction of the projects authorized by the BDCP and the successors to cover project operations for sequential ten-year periods.

Finally, although the fish and wildlife agencies retain the authority to revoke the incidental take permits—and thus to rescind the BDCP—if necessary to avoid jeopardizing any listed species, the draft Plan makes it difficult to do so by requiring the federal agencies to take action against other stressors on the species before determine that it is necessary to revoking the permits. The draft also removes the revocation decision from the federal agencies themselves and places it with the Cabinet-level Secretaries in whose Department the fish and wildlife agencies are located. We believe that these heightened substantive and procedural requirements reduce the likelihood that permit revocation would serve as an effective backstop in the event that the BDCP fails to achieve its overriding purposes of ensuring the survival and contributing to the recovery of the species. Indeed, these limitations on permit revocation strengthen our conclusions that the governance problems described throughout this chapter be repaired so that the fish and wildlife agencies retain the authority to insist on changes to the biological objectives and conservation measures of the BDCP as required to achieve species conservation and recovery.

CHAPTER 9: SCIENCE AND ADAPTIVE MANAGEMENT IN BDCP

Introduction

From the outset BDCP makes it clear that it will be science-based and adhere to the principles of adaptive management. The plan recognizes that all 22 conservation measures that are designed to meet the plan goals and objectives face high levels of uncertainty and that measures used to implement them will inevitably require adjustment and refinement. Indeed, given the unprecedented complexity of BDCP, it will most certainly fail without substantial investments in a program of science and monitoring linked to a robust adaptive management program that allows it to change course.

At the time of this review, the science and adaptive management component of BDCP was, by the project proponents' own admission, a work in progress with many of the key elements yet to be determined. We briefly review here the available information with the understanding that these elements are likely to change, possibly considerably, before the public draft is released.

Adaptive Management Program

The plan documents recognize that BDCP is compelled to adhere to an array of standards for adaptive management of the program (summarized in Chapter 3 of BDCP). This includes requirements of USFWS and NMFS five-point policy on adaptive management (65 Fed. Reg. 35241-35257), NCCPA requirements for monitoring and adaptive management programs (Fish & Game Code § 2820(a)(7) & (8), and the requirements of the Delta Reform Act for science-based adaptive management of all ecosystem and water management programs in the Delta (Water Code § 85308(f)).

The BDCP documents describe the well-known adaptive management cycle involving: *plan*, where management problems are recognized leading up to a plan of action to test management actions, *do*, where plans are implemented, accompanied by monitoring, and *evaluate*, where monitoring information is evaluated to measure effectiveness, and information learned initiates anew the planning portion of the cycle. As described in BDCP, the conceptual approach to adaptive management is closely aligned to the approach codified in the Delta Plan and the draft Delta Science Plan.

Governance and Implementation of Adaptive Management

BDCP envisions that its adaptive management program will be organized and run by its Implementation Office. The office will be run by a Program Manager who will be hired by the Authorized Entity Group (AEG). The AEG will be made up of DWR, Reclamation, and the state and federal water contractors. The Program Manager selects and supervises a Science Manager, who takes on the responsibilities of running the adaptive management programs and coordinating, in unspecified ways, all science and monitoring activities.

The Science Manager will chair and manage an Adaptive Management Team (AMT) made up of a broad array of regulators, regulated entities, and science programs. These include representatives appointed by members of the AEG, the Permit Oversight Group (POG: CDFW, USFWS, NMFS), the Interagency Ecological Program (IEP), Delta Science Program (DSP), and NOAA Southwest Fisheries Science Center. This group will receive input from a Technical Facilitation Subgroup, part of a Stakeholder Council made up of multiple of stakeholder groups, regulated entities, and regulating entities.

The AMT, led by the Science Manager, will have the responsibility for designing, administering and evaluating the BDCP adaptive management program, including the development of performance measures, monitoring and research plans, synthesis of data, solicitation of independent review, and developing proposals to modify biological goals and objectives as well as conservations measures.

The AMT is to operate by consensus only, meaning all members must agree to all actions. Where consensus cannot be reached the matter is elevated to the AEG and POG for resolution. As a matter of course, all changes in conservation measures and biological goals and objectives must be approved by the POG and AEG. The entity responsible for decisionmaking (for example, NMFS regarding changes in biological goals and objectives for salmon) will decide the issue. However, as discussed in Chapter 8, *any member of the AEG or POG may request review of the decision at the highest level of the relevant federal department or state, up to the appropriate department secretary or the Governor of California* (BDCP Chapter 7, Section 7.1.7).

An essential goal of the adaptive management program—seeking consensus for all decisions from all regulated and regulating entities as well as key providers of science—is understandable and, if it could be achieved, laudable. However, for several reasons this is unlikely to be successful.

First, as discussed in Chapter 8, this structure confuses the roles of regulators and regulated entities. It gives exceptional decision power to regulated entities, particularly those with a great financial stake in outcomes (state and federal water contractors). We are skeptical that difficult, perhaps costly decisions could be achieved in an efficient and effective manner since *any* member of the AEG or POG can, in effect, elevate any decision, no matter how trivial, to the highest levels of government. This is likely to have a chilling effect on decisionmaking, making all parties cautious and risk-averse. These traits—caution and fear of taking risks—are antithetical to the principles of adaptive management by which all management decisions are viewed as experimental and inherently risky. The most likely outcome from this approach to governance of adaptive management is that preliminary decisions made during the initial phases of the plan are, through sheer inertia, likely to remain permanent, rendering the concept of adaptive management moot.

Second, the AMT is made up of a mix of regulators, regulated entities, and scientific providers such as IEP and DSP. This places the science providers in the position of being decisionmakers, creating clear conflicts of interest. Most importantly, as discussed below, this eliminates one of the most important aspects of science in support of adaptive management: scientific independence.

Adaptive Capacity

The AMT, with approval from the POG, AEG or higher federal and state authorities, will oversee implementation of the adaptive management program, presumably through the Science Manager. A central issue likely to arise when finalizing BDCP is the adaptive flexibility available. All such programs have a natural tension between wanting to provide assurances—such as how much water will be exported from the Delta—and needing flexibility in amount and timing of exports to test and implement adaptive management programs. The current BDCP documents offer little to no guidance on adaptive capacity. This is likely to play a major role in how adjustments are made in conservation measures and, more importantly, how real-time operations (an element of adaptive management) are implemented. BDCP has sought to defer this decision, both within the document and to its Decision Tree process (discussed below).

Science Program

Science should underpin the discussions and information needed to make and implement adaptive management decisions. The extensive literature on adaptive management cites a strong, well-funded, and well-organized science and monitoring program as essential for adaptive management. The BDCP documents do not provide extensive information about science to support adaptive management, other than a solid commitment to build and support a strong science program and, in the EIR/EIS, a significant funding commitment. As currently described, the science program would be run by the Science Manager under the direction of the Program Manager and the AEG. The role of the science manager would be to fund an array of activities, guide synthesis and analysis, and coordinate with the numerous public and private institutions working on the Delta. Beyond this, there are few specifics.

BDCP's current efforts on science have come in for extensive criticism from several entities, including the National Research Council (2012), the Delta Independent Science Board (Memo to Delta Stewardship Council dated May 20, 2013) and the Public Policy Institute of California (Hanak et al., 2013, Gray et al., 2013). To be fair, the project proponents recognize that the BDCP science program is a work in progress and likely to change before the public draft of the plan is released. However, several significant issues will need to be resolved:

- *Integration*: the National Research Council in its review of Delta science was highly critical of the lack of integration of scientific efforts in the Delta. The NRC and others have pointed out that coordination is less effective than integration. BDCP is a once-in-a-generation opportunity to reorganize science in the Delta to make it more integrated and more effective for addressing the major issues of the day. As structured, BDCP builds a new stand-alone science program that seeks to coordinate with other programs, such as IEP and DSP, rather than to integrate them. This is unlikely to prove successful.

- *Independence*: as noted above, the AMT blurs the distinction among decision-makers, regulated entities, and the providers of science and technical advice. In addition, the BDCP science program is, in effect, run by the regulated entities and lacks independence. This creates the potential for bias in the selection of what science gets funded and what is ultimately made available to the public. Given that most major disputes in the Delta come down to differences of opinion in court about the best available science, demonstrating scientific integrity and transparency should be the highest priority.
- *Oversight*: as currently structured, there is no independent oversight of the BDCP science program. There is a commitment to promoting peer-review of scientific work products and plans. In addition, there is mention of coordinating with the existing DSP and the Delta Independent Science Board. But oversight, which is essential for creating public assurances that the best available science is being utilized in decision-making, is currently absent from the plan.
- *Funding*: science is expensive, and for a program this large and complex, it is likely to be *very* expensive. There are no discussions regarding budget in the BDCP plan documents. However, in the administrative draft EIR/EIS there are substantial commitments to funding a science program. There are categories of funding (monitoring, research, etc.), but little information as to how it would be distributed, organized and administered. Still, this level of commitment is significant and necessary.

To be effective, during revision of the plan documents, BDCP will have to address the considerable weaknesses in science governance, integration with other programs, independence and transparency, oversight and funding. Notably, there is a parallel process underway, led by the DSC, to develop a comprehensive plan for science in the Delta. This “One Delta, One Science” effort is essential for the success of BDCP. It seems to us that BDCP’s science effort should be fully integrated with the Delta Science Plan, if not led by the DSP. However, to date, BDCP has had limited involvement with this planning process.

Decision Tree

Earlier chapters of this review note that most controversial decisions, or decisions with high scientific uncertainty, are proposed to be resolved through adaptive management (i.e., *deferred*). One of the most important decisions will involve initial operations of the dual export facilities approximately ten years after issuance of the HCP/NCCP permit. The operations are to be based on the best available science on how to meet the co-equal goals of ecosystem benefit and water supply, with the goal of meeting the HCP/NCCP conservation standards.

A fundamental tension exists between two competing hypotheses regarding BDCP. The first, controlling hypothesis is that better management of existing export volumes with the dual facility, coupled with significant investments in floodplain, channel margin, and tidal marsh habitat to improve food webs, will improve conditions for covered species sufficiently to meet the HCP/NCCP standards. The second, embedded within the agency red flag comments and "progress reports", is that these steps are insufficient and that lower exports (higher outflow) will be needed to meet these standards. This issue is a paramount concern since it directly affects the economic viability of water supplied from the project.

As part of CM#1, BDCP will use a decision tree to address initial starting operations. As a starting point, BDCP embodies the two competing hypotheses in the LOS and HOS operating criteria, viewing them as brackets on the potential range of operations. The goal of the decision tree is to conduct a series of detailed studies and experiments to develop specific flow criteria, particularly for spring outflow (longfin smelt) and Fall X2 (delta smelt), in the decade before operation of the export facility begins.

The decision tree is the first, and probably most important, element of the BDCP adaptive management program. Much of the success of the adaptive management program will be tied to this element, since the original adaptive management and science infrastructure will presumably be built around addressing the competing hypotheses.

The decision tree approach to addressing starting operations is, in our view, laudable and appropriate. It makes no sense to wait until all uncertainties over this issue are resolved (a course of action proposed by diverse stakeholder groups). Experience says this issue will never be resolved to everyone's satisfaction and will require constant (and contentious) adaptive management. This is a necessary and appropriate step. Regrettably, there is little information given in the BDCP documents about how the decision tree would be implemented, including who would fund it, how it would be structured, how decisions would be made, what science experiments would be conducted, etc. The lack of detail about the decision tree in the BDCP documents raises several key concerns:

- It takes time to develop and implement a large, complex scientific undertaking of the kind envisioned by the decision tree approach. The POD crisis in the mid-2000's and the mobilization of the scientific community to address it is an example of a successful approach. But that still took considerable time and many issues addressed by the POD effort remain unresolved.

- To inform the potential placement and design of habitat restoration efforts to support food webs, new approaches to numerical modeling will be needed that better represent how these habitats function. Finding and funding the technical teams for this kind of work will take time and resources. A particular concern is whether contracting will be run through existing state and federal agencies who are notoriously slow at developing contracts.

- In addition, field experiments will be needed to inform and calibrate these models. This involves identifying locations to conduct experiments, modeling and designing actions, acquiring land or easements, implementing pre-project monitoring programs, implementing actions, monitoring responses, and incorporating results into system models. All of these actions take time and resources, but as is well-known by anyone working on ecosystem restoration in the Delta, the rate-limiting step is inevitably the length of time it takes to secure permits (see recent review in Hanak et al., 2013).
- Because any decision made regarding flow and habitat will have multiple, competing constituencies and regulatory interests, an extensive and often contentious public engagement effort will be needed. The history of the Delta suggests that all such significant decisions are litigated, further slowing this process.

These four concerns, as well as others, make us skeptical that the decision tree is likely to achieve the goal of resolving operations issues within a 10 to 15 year time period. We cannot say with certainty that it will not be successful. A committed, well-funded, well-managed effort on the part of all parties may yield useful conclusions. However, given that this is the less likely outcome, it seems imperative that BDCP negotiate export operations criteria that, in the absence of a successful decision tree process, will be implemented at the start of the project.

Our work in previous chapters has cast doubt on the viability of the controlling hypothesis that underpins BDCP. To this end, we think it prudent to, at minimum, adopt the HOS operating criteria as the starting condition if the decision try fails to identify operating procedures. In addition, if BDCP is truly committed to adaptive management and the use of best available science, it is not appropriate to set artificial boundaries—HOS and LOS—on the decision tree process. It is our view that the decision tree research effort should seek to define best operating procedures rather than being forced to operate within the HOS and LOS range. There is a reasonable chance that the decision tree process may ultimately determine that the HOS flow criteria are not protective enough.

Conclusion

The draft documentation provided by BDCP makes a strong commitment to the principles of adaptive management supported by a robust science program. Given the complexity of BDCP and the great scientific uncertainties underpinning many of the central elements of BDCP, this is absolutely necessary for success. As currently described, the BDCP adaptive management program either lacks sufficient information to be assessed or is unlikely to achieve its overall goals and objectives. This stems from two basic problems:

- The adaptive management program has a confused and conflicting governance structure that, in our view, is likely to inhibit adaptation rather than promote it.
- There is insufficient information, beyond funding levels, to judge how the science program might function and how the knowledge it generates would be converted to action. The current information in the documents indicates that the program lacks integration with existing programs, scientific independence and transparency, and sufficient independent oversight.

We recommend that BDCP seek substantive engagement (beyond "coordination") with the ongoing efforts by the DSC and the Delta Stewardship Council to develop a Delta Science Plan. The goal should be to integrate BDCP science and adaptive management into the broader science infrastructure of the Delta and not to construct a new, stand-alone science organization. Additionally, BDCP needs to revisit how adaptive management decisions are made, reallocating planning and decisionmaking authorities.

The decision tree process that seeks to resolve issues over initial operating criteria and habitat restoration investments is both appropriate and necessary. Unfortunately only limited information is available about this program so we cannot evaluate it. We are confident, however, that it is unlikely to resolve the major issues over the trade-offs between flow and ecosystem investments. For this reason, in the absence of resolution of decision tree process starting operations should be similar to HOS criteria.

Chapter 10: Summary and Recommendations

Introduction

We present a narrow review of aspects of BDCP that relate to conservation of federally listed fishes. We identify both strengths and weaknesses of BDCP's conservation measures in its effort to balance water supply reliability with ecosystem goals and objectives. Due to time and resource limits this review is incomplete. We did not examine all issues associated with aquatic ecosystems. For example, we did not evaluate habitat restoration on the San Joaquin River. Nor did we evaluate conservation issues for all covered fishes, giving limited attention to Sacramento splittail, San Joaquin steelhead, sturgeon and lamprey. Instead, we focused on the conservation measures that affect winter-run and spring-run Chinook salmon, delta smelt, and longfin smelt, because these measures are the most controversial and have greatest impacts on water supply operations. We also focused on a limited subset of the alternatives listed in BDCP documentation: the Early Long Term conditions under a No-Action Alternative (NAA), Low Outflow Scenario (LOS) and High Outlflow Scenario (HOS)[1].

We summarize our findings on the six guiding questions identified in Chapter 1, plus several recommendations sought by the NGOs after we began our work. These are intended to help inform The Nature Conservancy and American Rivers in their engagement efforts with BDCP. Where appropriate, we describe alternative approaches that might be taken for BDCP to more effectively meet its goals. On many issues we have no recommendations.

Question 1: Operations

Do operations of the dual facilities meet the broader goal of taking advantage of wet and above average years for exports while reducing pressure on below average, dry and critically dry years? What substantive changes in operations (and responses, see below) are there both seasonally and interannually?

We analyzed the CALSIM data on export operations under NAA , HOS and LOS for ELT conditions. We note that the modeling of flows under BDCP has three compounding uncertainties: uncertainty over system understanding and future conditions, model uncertainties associated with CALSIM, DSM2 and UnTrim, and behavioral/regulatory uncertainty, where the model cannot fully capture operational flexibility. For this reason, model outputs should be viewed as

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[1] NAA ELT is the no-project alternative using the 2008, 2009 BiOps with high spring outflow, 2025 climate and sea level conditions. LOS is with-project alternative with low fall and spring outflow, 2025 climate and sea level conditions. HOS is with-project alternative with high spring and fall outflow standards, 2025 climate and sea level conditions.

approximations useful for comparing different scenarios rather than as a predictor of future conditions. This issue influences all of our conclusions.

Based on our review we conclude:

- The array of existing and projected flow regulations significantly constrains operations in BDCP. The assumed operational flexibility associated with new North Delta facility is limited.
- HOS and LOS operations promote greater export during wet periods through increased use of North Delta diversions during the winter and spring. During dry and critical years, there is not much difference in *average* exports compared to NAA. For this reason, BDCP generally fails to meet the broader objective of reducing pressure on the Delta during dry periods.
- In some dry periods regulatory controls on OMR flows and North Delta diversions lead to significant increases in outflow and OMR flows over NAA. These unexpected results are the consequence of stricter flow requirements for HOS and LOS and operations being tied to previous water-year type in the fall and early winter. We are unsure if the project would actually be operated this way under these conditions.
- We evaluated how NAA, HOS and LOS performed during extended droughts. Of the three scenarios, HOS appears to be most protective of both supply and ecosystems by reducing the frequency and duration of dead pool conditions on Sacramento Valley reservoirs and assuring higher spring and fall outflows.

Recommendations: caution must be used in interpreting CALSIM model results for both export and environmental performance of BDCP due to compounding uncertainties. However, modeling results suggest that overall flow conditions are improved over NAA.

Question 2: Impacts of North Delta Facility

Based on operations criteria, does the Plan properly identify ecological impacts likely to occur adjacent to and in the bypass reach downstream of the new North Delta diversion facilities? If there will be direct and indirect harm to listed species by the facilities, does the Plan prescribe sufficient mitigation measures?

We reviewed the Conservation Measures and Effects Analysis of BDCP, including supporting appendices to evaluate conditions upstream of the North Delta facility, as well as near- and far-field effects of the facility itself. Our focus was on winter- and spring-run Chinook salmon, rather than all covered species. Based on this review we conclude:

- The BDCP consultants have appropriately identified the range of impacts on listed salmon likely to be associated with the operations of the North Delta facility. These include near-field effects such as impingement on intake screens and high predation losses at the facility, to far-field effects such as reduced survivorship of juvenile salmon due to higher transit times and redirection into the interior Delta. Using multiple modeling approaches, they have created reasonable estimates of losses due to operation of the facility.

- Mitigation for take associated with the new facility includes restricting diversion flows during initial pulse flows in the river, predator control, non-physical barriers, real-time operations to protect outmigrants, and modification of the Fremont Weir to divert fish onto the Yolo Bypass. With the possible exception of benefits from Fremont Weir modifications the uncertainties over mitigation actions are all high.
- We see high potential value in the Yolo Bypass for mitigating the effects of North Delta diversions on juvenile salmon, particularly in drier conditions. Therefore, existing adaptive management programs on the Bypass must be supported, with accelerated pilot studies, monitoring and ecological modeling, to ensure success of any modifications of the Bypass.
- Mitigation is hampered by the lack of a viable adaptive management plan or real-time management plan in the current BDCP for the North Delta facility. Still, even with these uncertainties, if managed well, fully implemented and functioning as described in the plan, the actions appear to mitigate for losses associated with the North Delta facilities.
- These mitigation efforts alone are unlikely to lead to significant increases in salmon populations, and extinction risk remains high for winter- and spring-run Chinook salmon, particularly during extended drought and warm periods when reservoirs are low. However, reservoir management is not within the scope of BDCP.

Recommendations: given the uncertainties over mitigation for the North Delta facility, we recommend that all mitigation actions be evaluated and completed prior to initiating operations the North Delta facility. Of highest priority is to bolster and complete adaptive management activities in progress on the Yolo Bypass. Additionally, we recommend establishing an adaptive management and real-time management program with the capacity to conduct significant experiments in flow management, predator control, and non-physical barrier implementation *prior* to initiating facility operation. These should be conditions of the HCP/NCCP take permit.

Question 3: In-Delta Conditions

Are changes in operations and points of diversion prescribed in the Plan sufficient to significantly improve in-Delta conditions for covered species? The focus is on listed species, including delta and longfin smelt, steelhead, winter and spring run Chinook, and green sturgeon.

We focused our analysis on in-Delta conditions that may affect delta smelt and longfin smelt. We reviewed the effects analysis and supporting documentation and conducted our own modeling based on CALSIM output. Based on this work we conclude:

- The CALSIM output we used showed conditions that appeared anomalous based on our understanding of how the system would actually be operated. Although we have been assured that these conditions were logical consequences of model design and operation to meet flow requirements, we remain unconvinced that they reflect actual future operations under the hydrologic conditions simulated. We therefore caution that **the conclusions below are contingent upon the actual operations of the system resembling those in the model output.** They are also contingent on the biological models accurately reflecting responses of the species to flow conditions.

- Roughly half of the export from the Delta will go through the North Delta facility. In addition, OMR flow regulations are more restrictive (protective) under HOS and LOS scenarios than NAA. Thus the incidence of positive OMR flows rose from 11% under NAA to 16% under HOS and LOS conditions. HOS and LOS are consistently more protective of smelt than NAA under these modeling assumptions.

- OMR flow regulation under HOS and LOS for October through January is governed by previous water year type. This leads to anomalously high (positive) OMR flows and corresponding outflow during some dry periods, creating apparent benefits for delta smelt. We are uncertain if this would manifest in real operations.

- Entrainment results in fractional population losses of delta smelt that can be calculated from modeled flow conditions. Based on these calculations, we estimate that HOS and LOS reduced fractional population losses by half compared to NAA. If actual operations were similar to the model results, they would lead to significant decreases in entrainment.

- Estimates of relative differences in long-term survival percentages (not predictions) showed a 19-fold increase for HOS and 11-fold increase for LOS over NAA, albeit with large uncertainty. A difference of this magnitude over the last 20 years would have reversed the decline of delta smelt in the 2000s.

- Increases in spring outflow are projected by the models to produce only a very small increase in longfin smelt abundance index under HOS compared to NAA, and a comparable decrease under LOS.

- Increases in fall outflow under HOS are projected to produce a small increase in recruitment by the following summer, and under LOS a modest decrease, but because of high variability in the data used to make these predictions, these values are very uncertain.

Recommendations: we remain uncertain about significant reduction in fractional population losses of delta smelt under the new HOS and LOS operating criteria. We recommend investment in resolving these uncertainties before operations are finalized. If these relationships are supported, then operational rules need to be refined to protect the benefits of these improvements over a broad range of conditions.

Question 4: Benefits of Habitat Restoration

Are covered pelagic fish like longfin smelt and delta smelt likely to benefit from restoration of floodplain and tidal marsh habitat at the scale proposed by the Plan? Given the current state of knowledge, and assuming that all Plan commitments are met, are these efforts likely to result in relaxed X2 and spring outflow standards?

A fundamental hypothesis embedded in the BDCP goals and objectives is that improvements in physical habitat, particularly floodplain and tidal marsh, will improve conditions for covered fishes. We focused our assessment on the relationship between habitat restoration and longfin and delta smelt. Based on this analysis we conclude:

- BDCP correctly identifies food limitation as a significant stressor on delta and longfin smelt, particularly in spring through fall. Increasing food availability in smelt rearing areas would likely lead to increases in population.
- Tidal marshes can be sources or sinks for phytoplankton and zooplankton. Most appear to be sinks, particularly for zooplankton. There is high on-site consumption of productivity within marshes.
- Even under the most highly favorable assumptions, restored marshes would have at best a minor contribution to plankton production in smelt rearing areas.
- Smelt can benefit by having direct access to enhanced productivity. This is likely the case for the subpopulation of smelt that reside in Cache Slough.
- BDCP is too optimistic about benefits of tidal marsh and floodplain restoration for smelt, particularly the extent of food production. These optimistic views are indirectly guiding the LOS outflow criteria. There is no clear connection, however, between the two and investments in marsh restoration are unlikely to lead to reduced demand for outflows.

Recommendations: it is possible but unlikely that marsh restoration will materially improve conditions for smelt, although other ecosystem and species benefits of marsh restoration are much more likely. Only moderate- to large-scale experimental restoration projects are likely to resolve this uncertainty and to help in designing future efforts. BDCP should design and describe a specific program to resolve this issue. Until this uncertainty is resolved flow management will remain the principal tool to mitigate project impacts.

Question 5: Governance

Does the Plan provide achievable, clear and measurable goals and objectives, as well as governance that is transparent and resilient to political and special interest influence?

We analyzed the proposed governance structure of BDCP, including the responsibilities and authorities of new entities such as the Authorized Entity Group (AEG), the Permit Oversight Group (POG), the Adaptive Management Team (AMT), Implementation Office, Program Manager and Program Scientist. Based on this review we conclude the following:

- The governance plan, as structured, blurs the responsibilities between implementation and regulation. It grants AEG final decisionmaking power over actions that should be solely within the authority of the permitting agencies. It also involves the permitting agencies too heavily in implementation of the project.
- As written, the plan grants the AEG veto authority over proposed changes in the program, including any changes in biological goals and objectives or conservation measures.
- The AEG has the power to veto any minor modification, revision or amendment to the Plan that may be necessary to manage listed species.
- The regulatory assurances set forth in the draft Plan severely constrain the fish agencies' ability to respond to inadequacies in biological objectives.
- Given the high uncertainties inherent in BDCP, it is very likely that unforeseen circumstances will require significant changes in biological goals and objectives and conservation actions. Under the 50-year "no surprises" guarantee, the fish agencies assume financial responsibility for many significant changes. This liability could deter needed regulatory changes to BDCP and CVP/SWP operations.
- The procedural hurdles necessary to revoke the incidental take permit of BDCP are so great that revocation is unlikely to occur over the 50-year life of the permit. Indeed, permit revocation and termination of the BDCP would be unprecedented under both state and federal law.

Recommendations: The POG should be granted exclusive regulatory authority to determine whether budgets and workplans are consistent with the permit and to approve revisions to the biological goals and objectives or amendments to the plan. It should have the authority to initiate changes needed to insure protection of the covered species. The POG's functions should be limited to regulatory oversight rather than direct involvement in implementation. There should be a "no surprises" guarantee for construction of the project. Upon completion of the project, there should be renewable "no surprises" guarantees every ten years. These renewals should be based on conditions at the time of renewal and appropriateness of biological goals and objectives. This approach creates an incentive for all parties to adapt to changes in conditions to sustain covered species, rather than simply fulfilling obligations on conservation measures.

Question 6: Science and Adaptive Management

Is there a robust science and adaptive management plan for BDCP? As described, is the proposed "decision tree" likely to resolve major issues regarding Fall X2 and Spring Outflow prior to initial operations?

We reviewed the science and adaptive management plans in both the plan and EIS/EIR documents. Most issues with high uncertainty or controversy in the Plan are relegated to resolution through an adaptive management process. Based on the documentation, we conclude:

- Given the major uncertainties facing BDCP a robust, well-organized and nimble adaptive management plan will be necessary. The current plan adheres to and strongly promotes the principles of adaptive management and science.
- The requirement of unanimous consent for all decisions by the AMT, and veto power of any member of the AEG and POG is a barrier to adaptive management.
- There is a blurring of the responsibilities between regulators and those responsible for implementation of adaptive management that has the potential to create conflicts. There is a conflicting relationship between AMT decisionmaking and the scientific organizations providing support for decisonmaking.
- The plan recognizes the importance of adaptive capacity, meaning flexibility in operations and actions that allow for learning. Yet it does not describe this capacity in a meaningful way.
- There is almost no description of a science program. What is provided lacks evidence for integration with existing programs, transparency, independence from bias and influence, and structured oversight. These are all necessary for success.
- The decision tree process to establish initial operating conditions is appropriate. Done well, it can resolve many issues. However, it is unlikely to resolve the central issue over starting conditions in time to implement them.

- Although difficult decisions are relegated to a future adaptive management program, actually implementing such a program on such a scale will be very difficult and will require careful design. BDCP does not provide information sufficient to determine whether it will be effective. We remain skeptical that it will.

Recommendations: many of the recommendations for changes in governance made previously will go a long way toward improving the adaptive management program, including the separation of regulators from implementation efforts. However, the plan still needs a complete description of how its adaptive management program would function. The AMT, in whatever form it takes, should be advised by a science program, without scientists responsible for decisionmaking. The science program should be integrated with existing Delta science programs, rather than inventing a new parallel program. The best opportunity for integration is the current efforts to establish a Delta Science Plan through the Delta Science Program and Delta Stewardship Council. Given that the decision tree is unlikely to fully reduce uncertainties in time, coupled with our concerns over how the project would be operated rather than modeled, we recommend that default starting operating conditions be negotiated that approximates the HOS scenario, with a goal of identifying and operationalizing attributes of this scenario that are most beneficial to listed fishes.

Appendices

Appendix A: Operational rules for the North Delta Facility

Appendix B: Impaired Flows into an Impaired Estuary

Appendix C: Effects of changes in flow conditions on entrainment losses of delta smelt

Appendix D: Evidence for food limitation of the smelt species

Appendix E: Model of plankton subsidy from marsh to estuary

Appendix F: Effects of Floodplain Inundation

Appendix G: Can incidental take permits be issued to water contractors?

Appendix A: Operational rules for the proposed North Delta Facility (from Draft Administrative Bay Delta Conservation Plan).

Table 3.4.1-1. Water Operations Flow Criteria

<table>
<tr><th>Parameter</th><th>Criteria</th></tr>
<tr><td>Old and Middle River/San Joaquin inflow-export ratio</td><td>
October, November: Flows will not be more negative than an average of −2000 cfs during D-1641 San Joaquin River pulse periods, or −5,000 cfs during nonpulse periods.
November, December: Flows will not be more negative than an average of −5,000 cfs and no more negative than an average of −2,000 cfs when the delta smelt action 1 triggers.
January, February: Flows will not be more negative than an average of 0 cfs during wet years, −3,500 cfs during above-normal years, or −4,000 cfs during below-normal to critical years, except −5,000 in January of critical years.
March: Flows will not be more negative than an average of 0 cfs during wet or above-normal years or −3,500 cfs during below-normal to critical years.
April, May: Allowable flows depend on gaged flow measured at Vernalis. If Vernalis flow is below 5,000 cfs, OMR flows will not be more negative than −2,000 cfs. If Vernalis is 5,000 to 6,000 cfs, OMR flows will not be more negative than −1,000 cfs. If Vernalis exceeds 6,000 cfs, OMR flows will be at least 1,000 cfs. If Vernalis exceeds 10,000 cfs, OMR flows will be at least 2,000 cfs. If Vernalis exceeds 15,000 cfs, OMR flows will be at least 3,000 cfs. If Vernalis exceeds 30,000 cfs, OMR flows will be at least 6,000 cfs.
June: Similar to April, but if Vernalis is less than 3,500 cfs, OMR flows will not be more negative than −3,500 cfs. If Vernalis exceeds 3,500 cfs, OMR flows will be at least 0 cfs. If Vernalis exceeds 10,000 cfs, OMR flows will be at least 1,000 cfs. If Vernalis exceeds 15,000 cfs, OMR flows will be at least 2,000 cfs.
July, August, September: No constraints.
</td></tr>
<tr><td>Head of Old River gate operations</td><td>
December, June 16 to September 30: Operable gate will be open.
All other months: Operable gate will be partially or completely closed as needed to support OMR flow criterion and, via real-time operations, to minimize entrainment risk for outmigrant juvenile salmonids and/or manage San Joaquin River water quality.
</td></tr>
<tr><td>Spring outflow</td><td>
March, April, May: As described in Section 3.4.1.4.4, <i>Decision Trees</i>, initial operations will be determined through the use of a decision tree. If at the initiation of dual conveyance, the best available science resulting from structured hypothesis testing developed through a collaborative science program indicates that spring outflow is needed to achieve the longfin smelt abundance objective the following water operations would be implemented within the decision tree. The evaluated starting operations would be to provide a March–May average outflow scaled to the 90% forecast for the water year, with scaling as summarized in the table below.

<p>March–May Average Outflow Criteria for “High Outflow” Outcome of Spring Outflow Decision Tree</p>
<table>
<tr><th>Exceedance</th><th>Outflow criterion (cfs)</th></tr>
<tr><td>10%</td><td>>44,500</td></tr>
<tr><td>20%</td><td>>44,500</td></tr>
<tr><td>30%</td><td>>35,000</td></tr>
<tr><td>40%</td><td>>32,000</td></tr>
<tr><td>50%</td><td>>23,000</td></tr>
<tr><td>60%</td><td>17,209</td></tr>
</table></td></tr>
</table>

Table 3.4.1-1. Continued

Parameter	Criteria
	70% 13,274 80% 11,382 90% 9,178 • Alternatively, if best available science resulting from structured hypothesis testing developed through a collaborative science program shows that Delta foodweb has improved, and evidence from the collaborative science program shows that longfin smelt abundance is not strictly tied to spring outflow, the alternative operation under the decision tree for spring outflow would be to follow flow constraints established under the Bay-Delta Water Quality Control Plan. • February, June: Flow constraints established under the Bay-Delta Water Quality Control Plan will be followed. • All other months: No constraints.
Fall outflow	• September, October, November: As described in Section 3.4.1.4.4, *Decision Trees*, initial operations will be determined through the use of a decision tree. Within that tree, the evaluated starting operations would be to implement the USFWS (2008) BiOp requirements, and the alternative operation would be to revert to the Bay-Delta Water Quality Control Plan requirements. The alternative operation would be allowed, if the research and monitoring conducted through the collaborative science program show that the position of the low-salinity zone does not need to be located in Suisun Bay and the lower Delta, as required in the BiOp, to achieve the BDCP objectives for Delta smelt habitat and abundance. • All other months: No constraints.
Winter and summer outflow	• Flow constraints established under the Bay-Delta Water Quality Control Plan will be followed.
North Delta bypass flows	• October, November: Flows will exceed 7,000 cfs. • July, August, September: Flows will exceed 5,000 cfs. • December through June: Variable, as shown in **Error! Reference source not found.**.
Export to inflow ratio	The export to inflow (E:I) ratio for CM1 operations is under development. Two options are under consideration, with the primary difference being the location at which inflow from the Sacramento River is measured. Option 1 (assumed in the low-outflow scenario [LOS] and the evaluated starting operations [ESO] scenario): • Combined export rate is defined as the diversion rate of the Banks Pumping Plant and Jones Pumping Plant from the south Delta channels. • Delta inflow is defined as the sum of the Sacramento River flow downstream of the proposed north Delta diversion intakes, Yolo Bypass flow, Mokelumne River flow, Cosumnes River flow, Calaveras River flow, San Joaquin River flow at Vernalis, and other miscellaneous in-Delta flows. Option 2 (assumed in the high-outflow scenario [HOS]): • Combined export rate is defined as the sum of the diversion rate of the Banks Pumping Plant and Jones Pumping Plant from the south Delta channels and the diversion at the proposed north Delta intakes. • Delta inflow is defined as the sum of the Sacramento River flow at Freeport (upstream of the proposed north Delta diversion intakes), Yolo Bypass flow, Mokelumne River flow, Cosumnes River flow, Calaveras River flow, San Joaquin River flow at Vernalis, and other miscellaneous in-Delta flows.

OMR = Old and Middle Rivers

Table 3.4.1-2. Flow Criteria for North Delta Diversion Bypass Flows from December through June

Constant Low-Level Pumping (December–June)

Diversions up to 6% of river flow for flows greater than 5,000 cfs. No more than 300 cfs at any one intake.

Initial Pulse Protection

Low-level pumping maintained through the initial pulse period. For the purpose of monitoring, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% over a 5-day period and (2) flow greater than 12,000 cfs. Low-level pumping continues until (1) Wilkins Slough returns to prepulse flows (flow on first day of 5-day increase), (2) flows decrease for 5 consecutive days, or (3) flows are greater than 20,000 cfs for 10 consecutive days. After pulse period has ended, operations will return to the bypass flows identified below under Post-Pulse Operations. These parameters are for modeling purposes. Actual operations will be based on real-time monitoring of fish movement.

If the first flush begins before December 1, May bypass criteria must be initiated following first flush and the second pulse period will have the same protective operation.

Post-Pulse Operations

After initial flush(es), Level I operations apply. After 15 total days of bypass flows above 20,000 cfs, Level II operations apply. After 30 total days of bypass flows above 20,000 cfs, Level III operations apply.

Based on the objectives stated above, it is recommended to implement the following operating criteria:

- Bypass flows sufficient to prevent upstream tidal transport at two points of control: Sacramento River upstream of Sutter Slough and Sacramento River downstream of Georgiana Slough. These points are used to prevent upstream transport toward the proposed intakes and to prevent upstream transport into Georgiana Slough.

Level I			Level II			Level III		
December–April			December–April			December–April		
Sacramento River Flow			Sacramento River Flow			Sacramento River Flow		
Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low-level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 80% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 60% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 50% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,600 cfs plus 60% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,400 cfs plus 50% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	18,400 cfs plus 30% of the amount over 20,000 cfs	20,000 cfs	no limit	15,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,000 cfs plus 0% of the amount over 20,000 cfs

Table 3.4.1-2. Continued

May			May			May		
Sacramento River Flow			Sacramento River Flow			Sacramento River Flow		
Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low-level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 70% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 50% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 40% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,400 cfs plus 50% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,000 cfs plus 35% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	14,750 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	12,400 cfs plus 0% of the amount over 20,000 cfs
June			June			June		
Sacramento River Flow			Sacramento River Flow			Sacramento River Flow		
Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low-level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 60% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 40% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 30% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,200 cfs plus 40% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	12,600 cfs plus 20% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	10,800 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,400 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,600 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	11,800 cfs plus 0% of the amount over 20,000 cfs

Appendix B: Impaired flows into an impaired estuary

The Sacramento River watershed is the main source of inflow to the Delta and is integral to current operations of the SWP and CVP. The construction of a new North Delta facility will not change the reliance on the Sacramento watershed very much. However, in conjunction with limited changes in reservoir operations and modifications to the Yolo Bypass, it will alter the timing of inflows to the Delta.

One of the goals of BDCP and the Delta Plan is to create a more natural flow regime. As noted in Chapter 4, there is little natural about the landscape, and humans are fully integrated into the ecosystem. Still, returning more natural seasonal flow changes will help in managing species whose life history traits are tied to flow cues.

The projected changes in outflow under BDCP are presented in Figure 3.1. These monthly averages are compared to current (not ELT) unimpaired outflow from the Delta, an imperfect measure of outflow under unregulated conditions that can be used for comparison of BDCP scenarios. All alternatives, including the no-project alternatives, do little to alter the significant changes in Delta outflow regime. The winter flood pulse associated with high runoff from mixed rain/snow storms has been greatly reduced in all but wet years. More significantly, the spring snowmelt pulse is attenuated, and largely missing in most of the drier years. Only late summer/early fall baseflow seasons have flows that are equal to or larger than unimpaired conditions.

Since the Sacramento outflow is a dominant signature for estuarine conditions (second to tides), we examined the magnitude of change in inflow from the Sacramento and compared it to unimpaired flow conditions. We used two simple methods to illustrate the magnitude of change overall and relative changes between ELT scenarios. The first involves calculating a monthly impairment index, I, where:

I = (scenario flow)-(unimpaired flow)/(unimpaired flow)

Where I approaches 0, the scenario flow is less impaired, where $I > 0$ scenario flows exceed unimpaired flows and where $I < 0$, scenario flows are less than unimpaired flows. The magnitude of I is a simple way of describing the magnitude of seasonal impairment. These results are summarized in Figure 3.2 for all water year types.

The impairment index is strikingly similar in pattern for all year types, with high negative impairments during the winter and spring and high positive impairments for the summer and early fall. This result is surprising because there are only subtle differences between year classes. The only significant variation between year classes occurs in the late summer/early fall when Fall X2 outflow rules predominate.

This broad similarity in impairment highlights how uniform the hydrology of the Delta has become: an issue raised in Lund et al., 2007 and Hanak et al, 2011 as contributing to the regime change in Delta ecosystems. It also shows how little effect the HOS and LOS scenarios are likely to have on Sacramento inflows to the Delta.

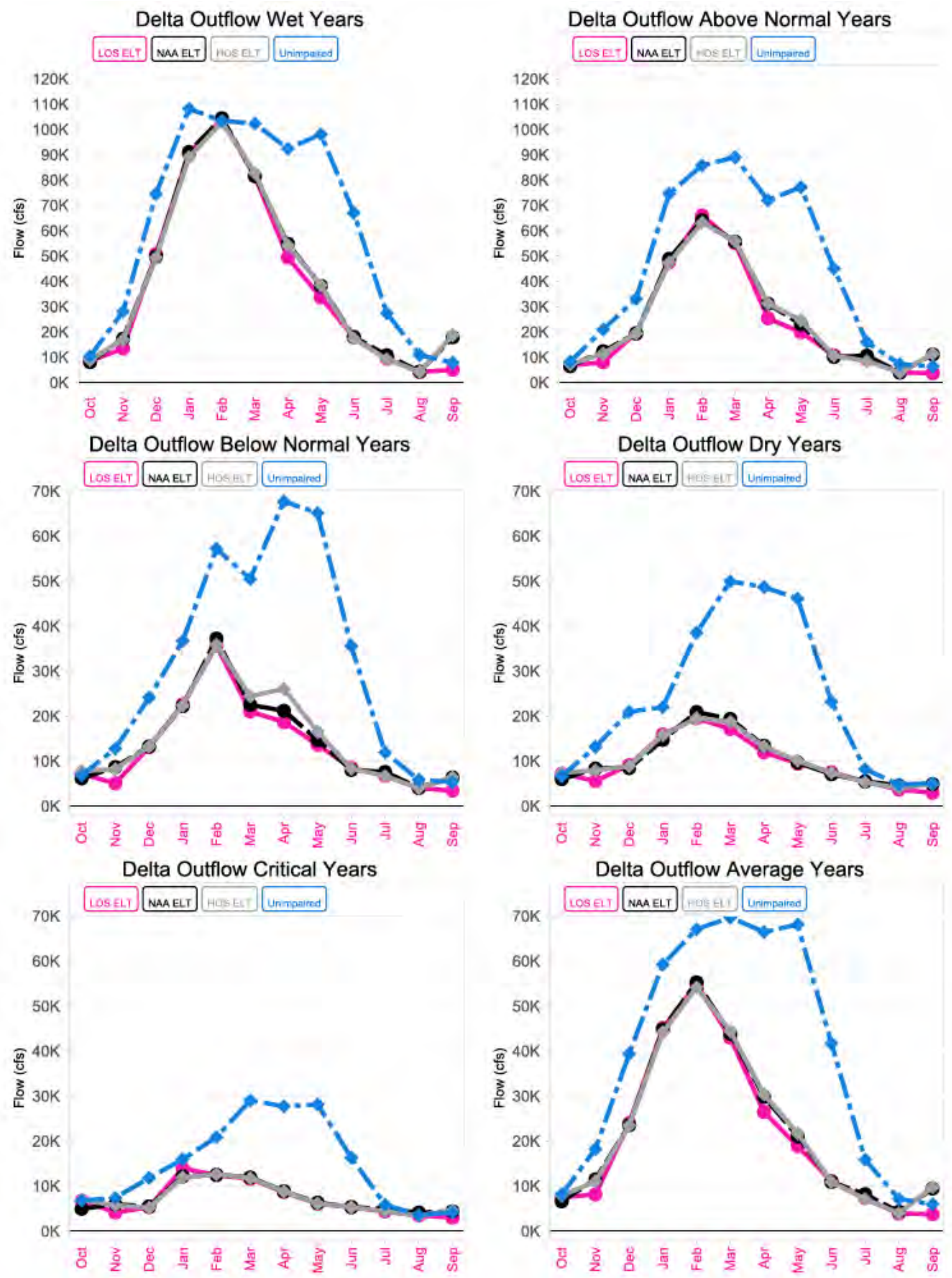

Figure 3.1: Delta outflow under HOS, LOS, and NAA ELT in comparison to unimpaired outflow

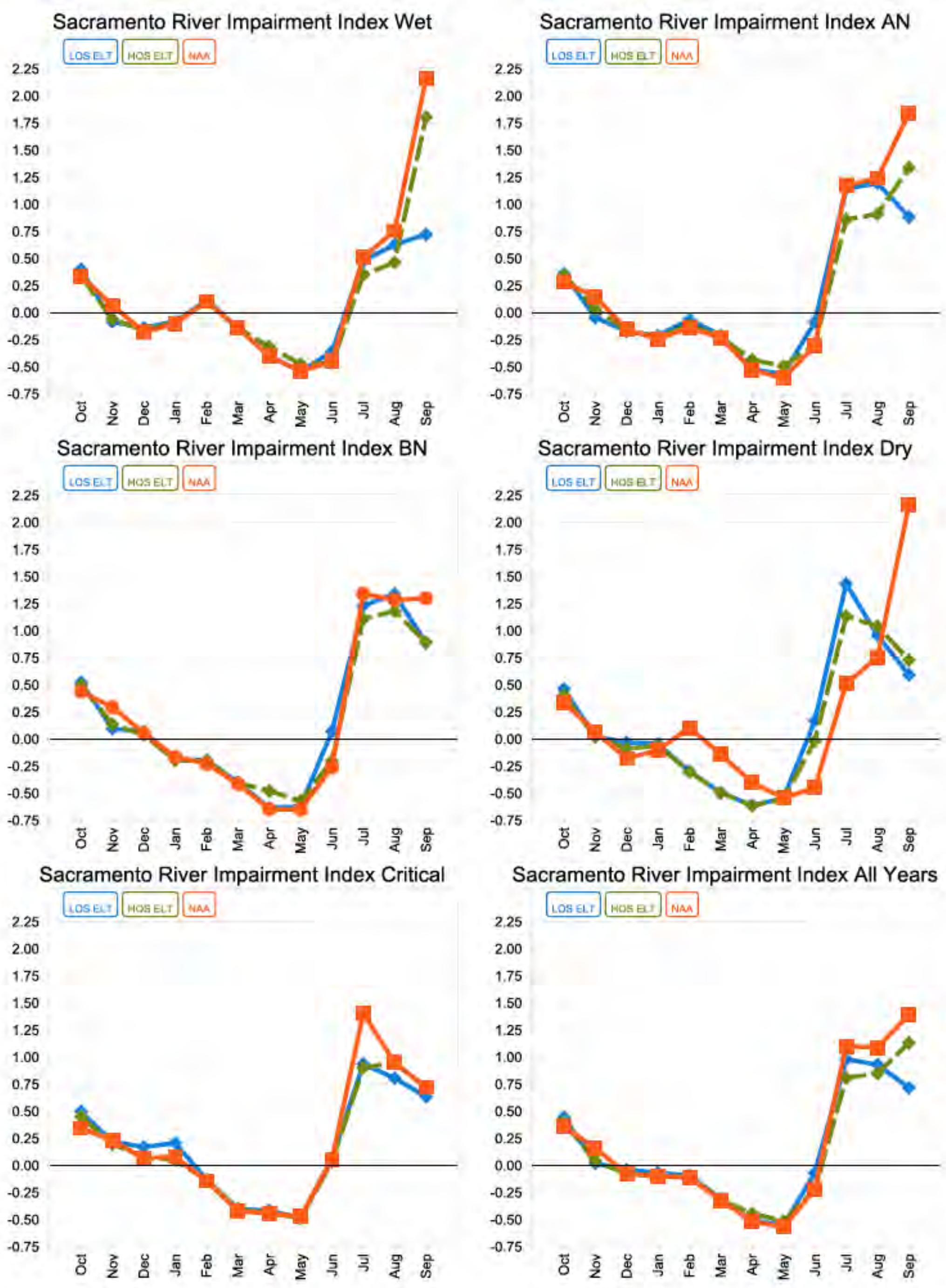

Figure 3.2: Sacramento River impairment index for HOS, LOS and NAA ELT.

A second approach can be used to characterize total impairment of individual year types. In this, we have plotted unimpaired vs. impaired flow for each scenario and each year type, and fitted a line and calculated r^2. The deviation of the slope of the line from 1 (impaired = unimpaired) illustrates the overall magnitude of impairment, while r^2 is a measure of variation in relative impairment. These results are shown in Figures 3.3-3.5.

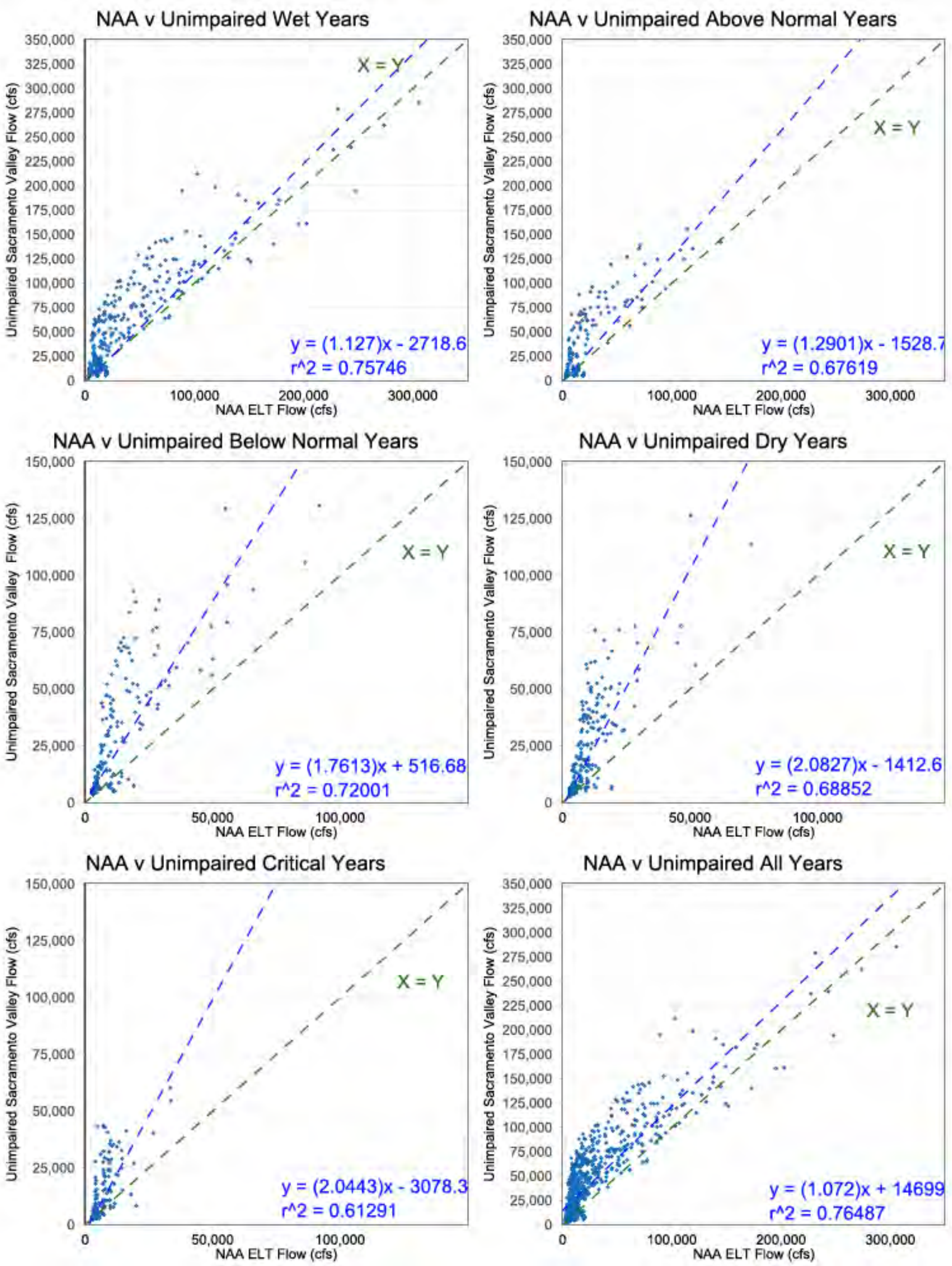

Figure 3.3. Scatterplot of NAA alternative Delta outflows vs. estimated unimpaired flows for ELT conditions. Higher slope and lower r² provide a relative measure of impairment.

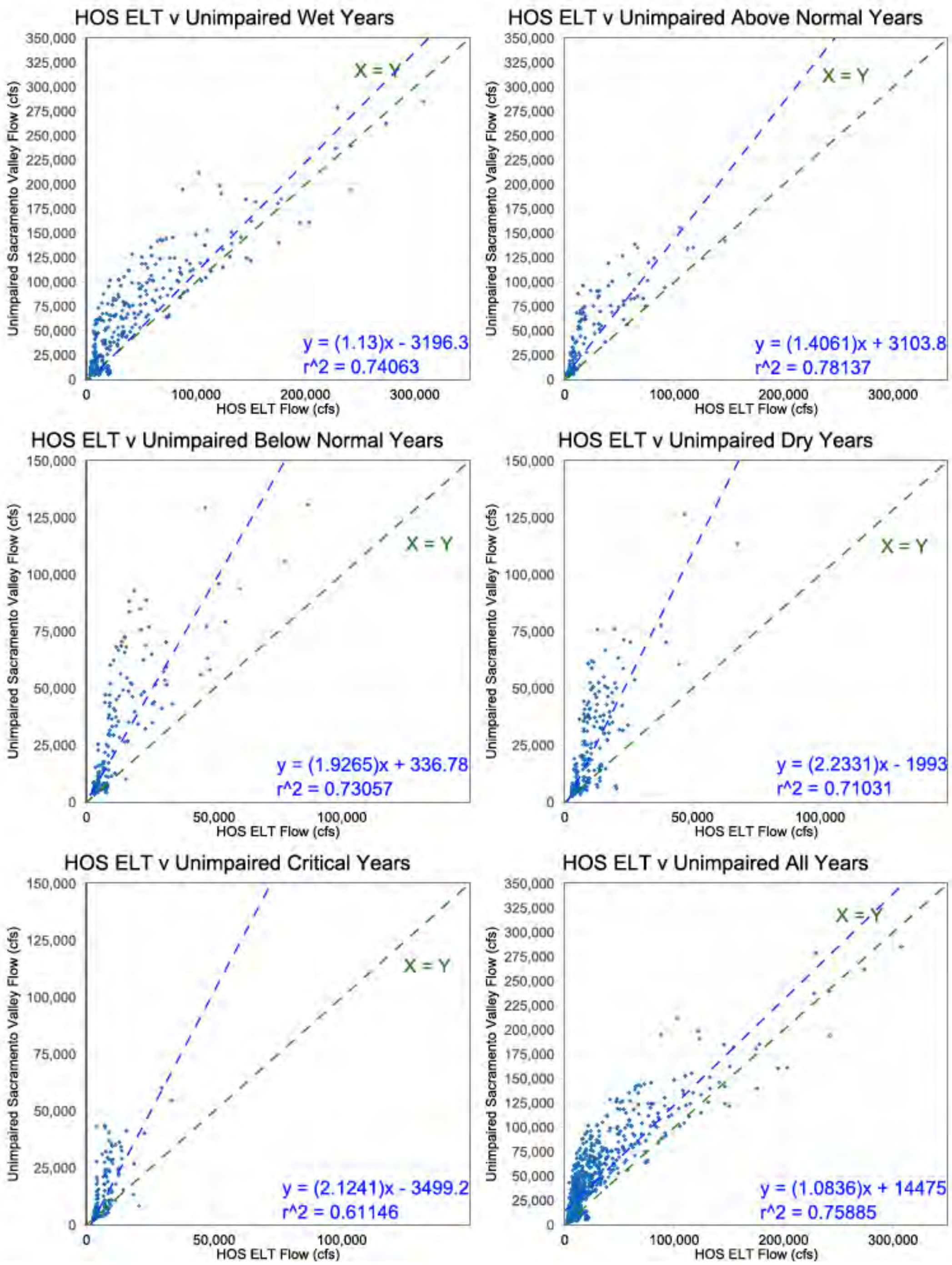

Figure 3.4: Scatterplot of HOS alternative Delta outflows vs. estimated unimpaired flows for ELT conditions. Higher slope and lower r² provide a relative measure of impairment.

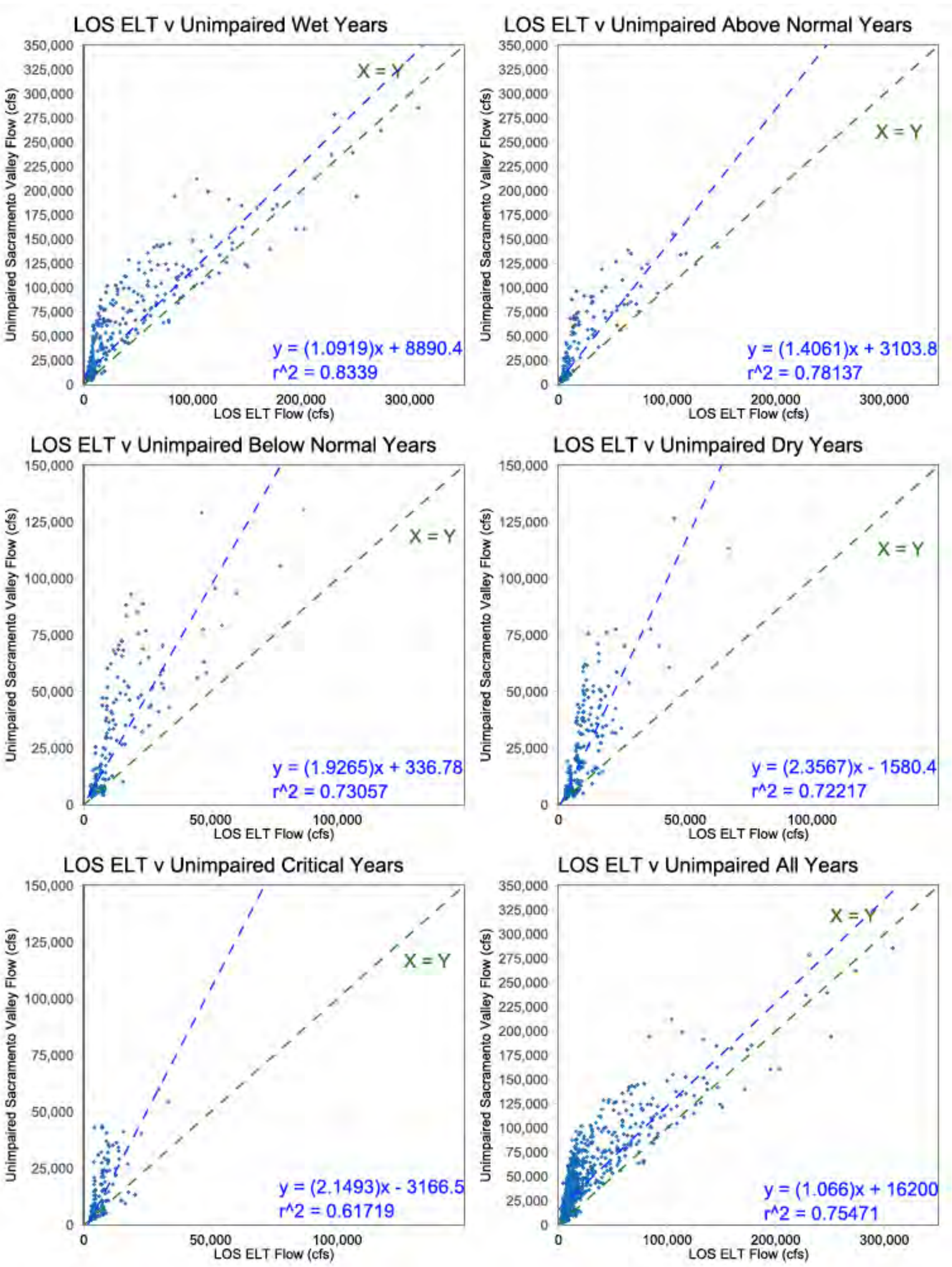

Figure 3.5. Scatterplot of HOS alternative Delta outflows vs. estimated unimpaired flows for ELT conditions. Higher slope and lower r^2 provide a relative measure of impairment.

The results of impairment scatterplots shows that in general, the magnitude of impairment, as measured by slope, and the magnitude of variation from unimpaired flow, as measured by r^2, are least in wet years and maximum in drier years. This reflects the dominance of water use and operations on Delta hydrology during dry years when the capacity for water alteration is greatest. In addition, there appears to be no substantive difference between the scatterplots of the different scenarios.

Conclusion

Examination of two closely related flow regimes, Delta outflow and Sacramento inflows, show that there is little difference in NAA, HOS, and LOS conditions. All represent high levels of impairment, in comparison to unimpaired flows, and the new North Delta facility and changes in export timing and magnitude have little impact on overall flow regime.

Appendix C: Effects of changes in flow conditions on entrainment losses of delta smelt

This Appendix describes the methods and results of analyses of flows in the South Delta and their potential effects on delta smelt. The general procedure was to determine a relationship between survival or recruitment during some life stages of delta smelt, and calculate the expected response based on conditions modeled using CALSIM and using historical data. CALSIM results were available for 1922-2003 for three BDCP scenarios: NAA, HOS and LOS. Historical data were used for inflow, export flow, and outflow during 1955-2003, and Old and Middle River flows from 1980 to 2003.

The calculations were based on results of Kimmerer (2008) as amended for adult delta smelt by Kimmerer (2011). Miller (2011) pointed out some potential biases in that analysis. Young delta smelt may be more abundant in the northern Delta than previously believed, which would mean that the proportional losses calculated by Kimmerer (2008) were too high (Miller 2011); however, this potential bias was not considered amenable to quantitative analysis with the available data (Kimmerer 2011). Nevertheless, the estimates of entrainment losses and reductions in losses herein may actually be somewhat overestimated.

The principal assumptions for this analysis are stated in Chapter 6. For the analyses of export losses we used a resampling method to account for uncertainty in the underlying statistical relationships between flow and entrainment. The error distributions from these models were sampled 1000 times to arrive at uncertainty estimates. The same 1000 samples were used for each year and scenario. This allowed us to include variability due to model uncertainty, and to allow direct comparisons among scenarios. The calculation was repeated for each year to provide the variability due to the hydrological conditions modeled under each scenario. Confidence limits were estimated as quantiles of the resulting set of simulated values for each parameter.

Losses of adult delta smelt

Losses as a proportion of the population of adult delta smelt had been estimated from salvage density, catches in the Spring Kodiak and Fall Midwater Trawl surveys, and flows in the south Delta (Kimmerer 2008, 2011). We related these estimates to total southward flow in Old and Middle Rivers:

$$Q_{sd} = mean_{Dec-Mar}\begin{pmatrix} 0, Q_{OM} \geq 0 \\ -Q_{OM}, Q_{OM} < 0 \end{pmatrix} \qquad (1)$$

where Q_{SD} is mean flow in the South Delta during December-March, and Q_{OM} is monthly mean or modeled flow in Old and Middle Rivers.

Estimated annual proportional losses P_L were related to Q_{SD} by linear regression for each year during which data were available (water years 1995-2006),

$$P_L \sim \max(0, a + bQ_{SD}) \tag{2}$$

where a=-0.03 and b= 0.0082 ± 0.0034 are regression coefficients. P_L was calculated using a revised estimate of the scaling factor Θ which accounts for uncertainty in the calculation of P_L; Θ has a mean of 22 and standard deviation of 5.2 (Kimmerer 2011).

Because P_L is a mortality we calculated means for a 20-year period by converting these values to survival, calculating geometric means, and converting back to proportions lost:

$$\overline{P_L} = 1 - \frac{1}{N}\prod_N (1 - P_{Li}) \tag{3}$$

where the overbar indicates a mean, N is the total number of years, and P_{Li} is the proportional loss for each year. The 20-year period was somewhat arbitrary but is roughly the timescale for the decline in abundance of delta smelt. To examine differences between pairs of the three scenarios we calculated the arithmetic means of differences for each pair.

There was little difference in mean P_L values between the full time series used in the analysis and the reduced time series that included the historical period (1980-2003). The No-Action Alternative (NAA) had a slightly lower percent annual loss than the historical period. The High and Low-Outflow scenarios (HOS and LOS) had similar values that were slightly below half of that of the NAA, or a net change in loss of about 3%/year.

Losses of juvenile delta smelt

Losses as a proportion of the population of juvenile delta smelt had been estimated from the spatial distribution of fish in the 20mm survey and flows in the south Delta supplemented by particle-tracking results (Kimmerer and Nobriga 2008, Kimmerer 2008). We related these estimates to total inflow to the Delta and export flow, noting that these results may vary depending on the proportion of inflow that is from the San Joaquin River. As with adults, CALSIM output was averaged over March – May for each year and scenario.

Annual proportional loss was calculated from a regression originally derived from particle-tracking data and applied to estimated losses of young smelt:

$$P_L \sim \max(0, a + bQ_{In} + cQ_{Ex} + dQ_{In}Q_{Ex}) \tag{4}$$

where a=-3, b= 0.36 ± 0.17, c= 0.90 ± 0.24, and d= -0.10 ± 0.03 are regression coefficients (Kimmerer 2008).

P_L values were accumulated and plotted as above (see Figures in Chapter 6). The annual means for the NAA were somewhat lower than the historical values, reflecting overall lower export flows than in the historical period. Both of the alternative scenarios resulted in substantial decreases in loss rates from about 14%/year to 3-5 %/year, and the LOS showed about a 2%/year higher loss rate than the HOS.

Appendix D: Evidence for food limitation of the smelt species

Delta smelt larvae consume mainly early life stages of copepods, switching to adult copepods as soon as they are able to catch and ingest them (Nobriga 2002, Hobbs et al. 2006, L. Sullivan, SFSU, pers. comm.). Juvenile delta smelt feed mainly on adult copepods (Moyle et al. 1992, Lott 1998, Nobriga 2002, Hobbs et al. 2006), although they consume other zooplankton such as cladocerans in freshwater. The diets of adults include larger organisms such as mysids and amphipods (Bippus et al. poster 2013; Johnson and Kimmerer 2013 talk).

Evidence in favor of food limitation (numbers in parentheses indicate the steps in the logic chain in Chapter 7)

Both smelt species

1. (1) Following the spread of the overbite clam *Potamocorbula* in 1987, sharp declines occurred in phytoplankton biomass and productivity, diatom production, and abundance of copepods and mysids, which are the principal prey of both species (Alpine and Cloern 1992, Kimmerer et al. 1994, Orsi and Mecum 1996, Kimmerer and Orsi 1996, Kimmerer 2005, Winder and Jassby 2011)
2. (1) At around the same time abundance indices of several fish species declined, notably anchovy, longfin smelt, and striped bass (Kimmerer 2002, 2006, Kimmerer et al. 2009), indicating an overall response of estuarine fish populations to the decline in food abundance. The decline in anchovy abundance in brackish waters (but not in high salinity) was particularly sharp and closely tied in time to the 1987 decline in phytoplankton biomass.

Delta smelt

3. (1) Gut fullness of delta smelt larvae was positively related to copepod density (Nobriga 2002). This suggests that when there is more food the smelt larvae eat more.
4. (1) Feyrer et al. (2003) found that delta smelt guts averaged about 40% full in Suisun Marsh before *Potamocorbula* arrived. This was similar to the gut fullness of most other fish species. It suggests that if there were more food the fish would have eaten more, or that there is some other limit to gut fullness.
5. (1) The functional response of larval delta smelt from laboratory experiments shows that the feeding rate saturates at a prey concentration well above that seen in any zooplankton samples in the smelt habitat during May –July of 1993-2011 (L. Sullivan, SFSU, unpublished; see Figure A7.1).

6. (2) Glycogen was depleted in 30% of fish in summer and 60% of fish in fall of 1999 (Fig. 28C in Bennett 2005) which could be interpreted as evidence of poor nutrition either because of a food shortage or because of some toxic effect; however the frequency of toxic damage was <10% in these fish.
7. (2) Mean lengths declined in either 1989 (Bay Study) or 1993 (FMWT study; Fig. 29 in Bennett 2005). The latter year is when the copepod *Pseudodiaptomus forbesi* shrank back from the LSZ in summer-fall, presumably because of the combined effects of clams and the introduction of other copepods. Bennett (2005, Figure 30) also showed positive relationships between mean length of delta smelt and copepod density (Bennett Fig. 30).
8. (3a) Copepod biomass is correlated with an index of survival from summer to fall (Kimmerer 2008).
9. (3a) Abundance data show evidence for density dependence between summer and fall when the early years are included (Bennett 2005 Fig. 17). A likely cause of density dependence is food limitation, although other mechanisms are also possible.
10. (1-4) Several model analyses show strong effects of food supply on the population rate of increase (Maunder and Deriso 2011, Rose et al. 2013a, b, Kimmerer and Rose, in prep). Note, however, that these models are incomplete and can only show effects based on what is in them.
11. A multivariate autoregressive (MAR) model (Mac Nally et al. 2010) showed weak support for a positive link between calanoid copepod abundance and delta smelt abundance index.

Longfin smelt

12. (1) Longfin smelt prey mainly on mysids after summer (Feyrer et al. 2003). Mysids declined sharply after 1987 (Orsi and Mecum 1996, Winder and Jassby 2011).
13. (Overall) Abundance of longfin smelt declined sharply after the introduction of *Potamocorbula*, when the strong effect of freshwater flow is taken into account (Kimmerer 2002, Kimmerer et al. 2009). Striped bass, which also feed on mysids (Feyrer et al. 2003), also declined at that time.
14. A multivariate autoregressive (MAR) model (Mac Nally et al. 2010) showed weak support for a positive link between calanoid copepod abundance and longfin smelt abundance index.

Evidence that does not support food limitation or is missing

15. The abundance of delta smelt did not change when *Potamocorbula* arrived or 1993, which were the two times of greatest change in calanoid copepod abundance in the low-salinity habitat of delta smelt

16. A changepoint model (Thomson et al. 2010) showed no link between abundance of various zooplankton and abundance indices of either smelt species.
17. Sampling for zooplankton is at too coarse a scale to represent the prey abundance that the smelt perceive, and the spatial distribution of prey cannot be replicated in the laboratory. Therefore it may be misleading to extrapolate functional responses from the laboratory to the field.
18. There is no direct evidence for effects of food on survival, maturity, or fecundity.

Appendix E: Model of plankton subsidy from marsh to estuary

Here we assume that the restored areas will actually produce an excess of phytoplankton or zooplankton over adjacent waters, and ask what additional level of food availability to the smelt would result. This is based on a very simple model and some calculations using data from IEP monitoring, as noted below. These calculations are unpublished except where a citation is given; details of calculations are available on request.

The additional zooplankton biomass available to the open-water areas as a result of production in restored shallow subtidal areas depends on the excess production in the restored areas, the resulting gradient in biomass, the tidal exchange rate between the restored areas and open waters, and the net population growth rate of the zooplankton in the open waters. The benefit of that additional supply to the smelt species depends on the proximity of the restored area to the population centers of the smelt (Fig. 7.2).

A simple model of this subsidy is:

$$F = (B_R - B)V_R X / BV \qquad (1)$$

where F (d^{-1})is the subsidy as a daily proportion of plankton biomass in the receiving water, B is biomass per unit volume, V is volume, B_R and V_R are biomass and volume in the restored area, and X is exchange rate as a daily proportion of the volume of the restored area (d^{-1}). Biomass and volume units cancel out.

It is clear from Equation 1 that the subsidy is maximized when the restored area is large, the zooplankton biomass in the restored area is well above that in the open water, and exchange rate is high. However, there is an the interplay among biomass B_R, volume V_R, and exchange rate X. First, water depth has three competing effects: 1) Phytoplankton growth rate is highest in shallow water where light penetration is high; 2) For a given area of restoration, volume is inversely related to water depth; 3) any bivalve grazing consumes phytoplankton and zooplankton in inverse proportion to depth. Second, as the exchange rate X increases, net population growth rate within the restored area decreases as organisms are removed by the exchange. If there is no exchange there is no subsidy, but at high levels of exchange there is also no subsidy because the zooplankton are being mixed rapidly compared to their internal growth processes (see Figure 7.3). Cloern (2007) showed that the efficiency of conversion of phytoplankton to zooplankton in a linked shallow-deep system was maximized when the tidal exchange rate X was equal to the net population growth rate of the primary consumers.

It is beyond our scope to model explicitly the growth and other processes and consequent biomass levels. However, it is possible to constrain the total phytoplankton and zooplankton biomass within a marsh using available data. During strong blooms nutrients are converted to phytoplankton biomass, but conversion is incomplete because some is lost to other foodweb components such as detritus, bacteria, and zooplankton. Thus, the total amount of dissolved inorganic nitrogen (DIN, comprising nitrate, nitrite, and ammonium) can set an upper limit to total phytoplankton biomass.

We used data from the IEP water quality and zooplankton monitoring programs from 1975-2012. Data used were from May to October to avoid the high variability of winter flows, and to focus on the dry season when the smelt species may be most constrained by food supply. Data were taken from the low-salinity zone, extended to a salinity of 0.5 – 10, about the range of salinity where delta and longfin smelt are abundant in their first summer, and averaged by year and month.

Chlorophyll was converted to phytoplankton C using a carbon:chlorophyll ratio of 50, under the assumption of high light availability. To examine bloom conditions, we used only data for which phytoplankton biomass exceeded 200 mgC/m^3. From these data, we determined the zero-intercept of a linear model of phytoplankton carbon vs. dissolved inorganic nitrogen (DIN), under the assumption that this represented the maximum conversion of DIN to phytoplankton biomass. This corresponded to about 900 mgC/m^3 (about 40% of the sum of phytoplankton C and DIN converted to C using a molar ratio of 6.6:1). We used that value as the upper limit for phytoplankton C in a marsh. Calanoid copepod C for adults and copepodites was estimated to be about 2.5% of actual phytoplankton C, and we assumed that this proportion would apply to the maximum phytoplankton C, or about 23 mgC/m^3. Using the same data the median phytoplankton and calanoid copepod C in the open water during 1994 – 2011 were 73 and 3 mgC/m^3 respectively.

The optimum exchange rate was calculated separately for phytoplankton and for zooplankton. For calculation we assume a mean depth of 2m and an area of 1000 ha (2500 ac) in the restored area. From Lopez et al. (2006) the growth rate of phytoplankton in a shallow area can be modeled as

$$\mu_P = -0.09 + 1.91/H, \qquad (2)$$

where H is water depth. At a water depth of 2m, this evaluates to 0.86 d^{-1}, which we use although a similar model using data from the LSZ in 2006-2007 gave a growth rate that was about 25% lower. We assume that benthic grazing in the restored area is negligible, but cannot neglect grazing by microzooplankton. This can be modeled either as:

$$g = \max(0, 0.93\ \mu_P - 0.3) \qquad (3)$$

based on experimental results from the Low-Salinity Zone in 2006-2007 (York et al. 2011), or

$$g = 0.6\ \mu_P \qquad (4)$$

from a review of microzooplankton grazing estimates, using values for estuaries (Calbet and Landry 2004). These yield growth rates of 0.5 and 0.35 d^{-1} respectively. The latter value is probably more generally representative of a wide range of conditions and for this analysis gives a higher net phytoplankton growth rate.

Using an exchange coefficient X set to be close to the net phytoplankton growth rate less grazing of 0.35 d^{-1} and using the volume of the LSZ of 0.5 km^3 as V in Equation 1, we get:

$$F = (B_R - B)V_R X / BV = (900-73)\ (1000 \times 10^{-2} \times 2 \times 10^{-3})\ 0.35 / (73 \times 0.5)$$

or about 0.16 d^{-1}. This is about half of phytoplankton growth, and about twice the (negative) net of growth less grazing by microzooplankton and clams in the LSZ based on field measurements during 2006-2008, which is now subsidized by mixing from other areas of the estuary. Thus, the extremely ideal conditions proposed above would lead to a substantial subsidy of phytoplankton to the LSZ. However, this assumes nearly perfect tuning of the exchange, ideal growth of the phytoplankton with no benthic grazing within the restored area, and perfect mixing of the discharged phytoplankton into the LSZ, which is unlikely because of its tidal movement in relation to the outlet of any marsh.

For calanoid copepods the equivalent calculation to that above is

$$F = (23 - 3)\ (1000 \times 10^{-2}) \times (2 \times 10^{-3})\ 0.1 / (3 \times 0.5)$$

or about 0.03 d^{-1}. As before, this represents an upper limit of the likely subsidy to LSZ zooplankton. This corresponds to a turnover time of about a month, considerably longer than the population turnover time of the copepods. As with phytoplankton, this is an upper limit of the potential subsidy of copepods, which would be reduced by behavioral resistance to movement such as vertical migration, and by excess predation in the marsh compared to the adjacent open waters. Both of these reductions are likely to be very large.

Zooplankton export from Suisun Marsh

One of the proposed restoration areas is in the northern end of Suisun Marsh. Biomass of calanoid copepods in the southern part of the marsh was about 2× that of the adjacent Grizzly Bay, based on a short-term field study and long-term monitoring data (Kimmerer and Marcal 2004). Biomass in the smaller sloughs to the north is apparently higher although nothing has been published on that (J. Durand, UC Davis, pers. comm.).

We used output from the UnTRIM hydrodynamic model (MacWilliams et al. in prep., Kimmerer et al. in press) and the FISH-PTM particle tracking model (Kimmerer et al. in prep.) to examine the residence time of particles within Suisun Marsh during the dry season. The hydrodynamic model simulates the entire estuary including marsh channels and bathymetry, but is not specifically set up to replicate flows in the marsh and therefore the results should be considered preliminary. For the entire network of channels it should give acceptable results, but to model the smaller sloughs would require a finer grid for that area.

The PTM was run for 45 days in a dry period in the historical data set (starting 1 July 1994) to examine the influence of vertical movement on retention in the estuary. The model was started with particles released throughout the northern estuary in a pattern similar to the distribution of the copepod *Eurytemora affinis*, the most abundant LSZ resident zooplankton species before *Potamocorbula* was introduced. Over 9000 particles were released for each run at approximately the same number per unit volume throughout the marsh. Residence time was estimated as the rate of decline of the log of total particles remaining in the marsh.

For neutrally-buoyant (i.e., passive) particles, the residence time of the marsh was about 28 days, and particles continuously left the marsh during the 45-day run. Particles that either sank or migrated tidally (down on the ebb and up on the flood) had a more complex pattern but generally the particles in the northern part of the marsh did not leave the marsh during the 45-day run.

Taking the passive case first and using available bathymetric data for the volumes of the marsh and Suisun Bay, Equation 1 can be reduced to the following:

$$F = (B_R / B - 1) \times V_R / (RT \times V) = (B_R / B - 1) \times 0.07 / (28 \times 0.11)$$

$$= 0.02\ (B_R / B - 1)$$

Based on the existing data cited above for Suisun Marsh, this flux would provide an additional 2%/d of copepods to Suisun Bay if the copepods behaved as passive particles. This is unlikely to produce a noticeable increase in copepod biomass, as their population growth rates are on the order of 10%/d. Any tidal migration or tendency to remain near the bottom (which can be common among zooplankton in shallow, well-lit waters) would greatly reduce or even eliminate the net flux from the marsh to the open waters.

Appendix F: Effects of floodplain inundation

This Appendix explores available data on the response of phytoplankton and zooplankton biomass to flooding of the Yolo Bypass. This is to provide a basis for anticipating effects on the estuarine foodweb from floodplain inundation at lower flows in the Sacramento River.

One assumption underlying BDCP plans for increased inundation of the Yolo Bypass is that it would provide a source of phytoplankton and zooplankton to the open waters of the estuary. If so, the much larger floods that occasionally inundate the Bypass now should produce measurable increases in phytoplankton and zooplankton at monitoring stations in the estuary.

The basis for this analysis was to use the IEP monitoring data to try to detect an influence of inundation of the Bypass on phytoplankton biomass as chlorophyll concentration, and zooplankton biomass calculated from abundance. IEP data were obtained from six stations in the western Delta to eastern Suisun Bay.

Chlorophyll concentration has been determined since 1976 in the zooplankton survey. Abundance of zooplankton has been determined since 1972 by species and gross life stage. We used data on adult and juvenile calanoid copepods, which are common in the diets of delta smelt and other fishes. Abundance data were converted to biomass using carbon mass per individual by species and life stage (see Kimmerer 2006 for details; carbon estimates have been updated).

Neither chlorophyll nor copepod biomass showed any effect of inundation of the Bypass. This lack of response is clear for copepod biomass in Fig. F.1, which shows that under high flows in the Bypass the biomass was generally lower than when flows were lower. The data have been stratified by groups of years separated by the time that the clam *Potamocorbula amurensis* was introduced. During both periods biomass was generally higher when the Bypass was dry than when it was flowing at a low rate ($< 500\ m^3s^{-1}$). Biomass increased slightly in a handful of times when the Bypass was flowing at a higher rate, but even with this increase biomass still did not match that at the lowest flows. The difference in biomass between the pre- and post-clam period is notable at low Bypass flows.

Most of the high flows in the Bypass occurred during winter when zooplankton biomass is at its seasonal low. Inundation of the Bypass later in spring at a lower stage of the Sacramento River than is now necessary might provide conditions for higher productivity, but the lack of response of the current system at lower Bypass flows is not promising.

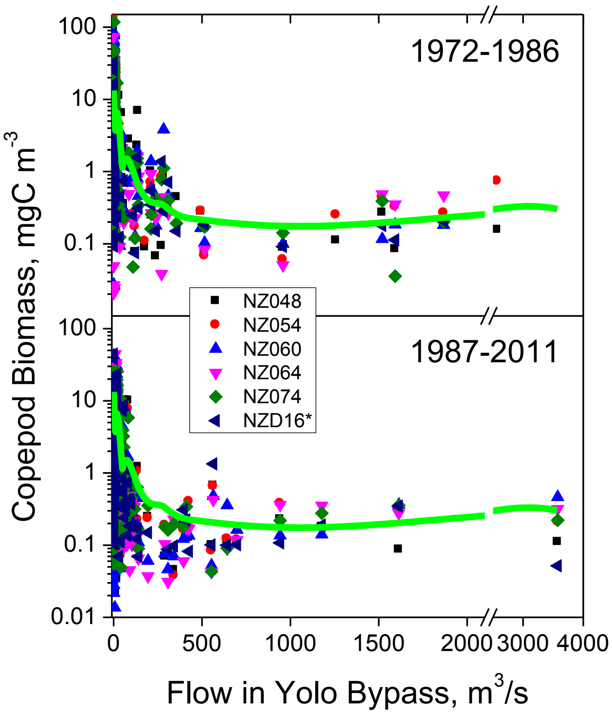

Figure F.1. Copepod biomass as a function of flow in the Yolo Bypass for two time periods. Symbol shapes and colors show the sampling stations from the IEP zooplankton monitoring survey. Green line is from a generalized additive model with a loess (locally-weighted) smoothing function applied to the pre-1987 period and shown in the lower graph for comparison.

Appendix G: Can incidental take permits be issued to water contractors?

Do the federal Endangered Species Act and the California Natural Community Conservation Planning Act allow the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Wildlife to issue incidental take permits to the Central Valley Project and State Water Project contractors?

This question is significant, because the draft BDCP provides that the Authorized Entity Group shall be comprised of the Director of the California Department of Water Resources as operator of the SWP, the Regional Director of the U.S. Bureau of Reclamation as operator of the CVP, and one representative each of the CVP and SWP contractors if the contractors are issued permits under the Plan. BDCP 7-8. If we correctly understand the premise of this question, it is that only the owners and operators of the two projects—the U.S. Bureau of Reclamation and the California Department of Water Resources—are eligible to hold the incidental take permit that would govern construction and operation of the facilities authorized by the BDCP.

Although there is no definitive answer to this question, we conclude that the CVP and SWP contractors may receive incidental take permits. We base this conclusion on four factors: (1) There is nothing in either the federal Endangered Species Act or the California Natural Community Conservation Planning Act that prohibits the fish and wildlife agencies from issuing incidental take permits to entities such as the CVP and SWP contractors who receive water service from (and therefore are beneficiaries of) the permitted project operators. (2) The text of both statutes allows for the grant of incidental take permits to persons or entities other than the owners and direct operators of the projects governed by an HCP and NCCP. (3) There is precedent for the inclusion of both government entities and private landowners and resource users within a single HCP/NCCP. (4) There are good reasons both for the CVP and SWP contractors to seek the protections of an incidental take permit and for the fish and wildlife agencies to include the contractors within the management structure of the BDCP. It is therefore likely that the courts would defer to the agencies' decision to issue incidental take permits to the contractors.

The incidental take permitting and HCP provisions of section 10 of the federal ESA authorize the taking of individual members of a listed species that otherwise would be prohibited by section 9(a)(1)(B) of the Act. 16 U.S.C. § 1538(a)(1)(B). The take prohibition of section 9 applies to "any person subject to the jurisdiction of the United States." *Id.* § 1538(a)(1). The statute defines "person" as meaning

> an individual, corporation, partnership, trust, association, or any other private entity; or any officer, employee, agent, department, or instrumentality of the Federal Government, of any State, municipality, or political subdivision of a State, or of any foreign government; any State, municipality, or political subdivision of a State; or any other entity subject to the jurisdiction of the United States. [*Id.* § 1532(13).]

This definition expressly includes the CVP and SWP contractors, which are comprised primarily of instrumentalities of the state (and, in the case of the CVP, includes some individuals). The statute thus extends eligibility for (limited and conditional) exemption from the take prohibition of section 9 to the project contractors, and it contains no exclusion from this eligibility based on the fact that the contractors do not themselves own or operate the project.

The California Natural Community Conservation Planning Act addresses this question even more directly. In its articulation of the purposes of the statute, the Legislature stated:

> Natural community conservation planning is a cooperative process that often involves local, state, and federal agencies and the public, including landowners within the plan area. The process should encourage the active participation and support of landowners and others in the conservation and stewardship of natural resources in the plan area during plan development using appropriate measures, including incentives. [California Fish & Game Code § 2801(j).]

The Act also declares that "Any person, or any local, state, or federal agency, independently, or in cooperation with other persons, may undertake natural community conservation planning." *Id.* § 2809.

Indeed, the fish and wildlife agencies approved this type of multiparty, multijurisdictional, cooperative approach in the Orange County HCP/NCCP for the protection of the coastal gnatcatcher, other target species, and their habitat. The cooperating and individually permitted entities include the County of Orange, the cities of Anaheim, Costa Mesa, Newport Beach, Irvine, Laguna Beach, Orange, and San Juan Capistrano, as well as other participating public and private landowners and water users, such as Southern California Edison, the Metropolitan Water District, Irvine Ranch Water District, the Irvine Company, UC Irvine, the California Department of Parks and Recreation, and transportation corridor agencies. COUNTY OF ORANGE, FINAL NATURAL COMMUNITY CONSERVATION PLAN AND HABITAT CONSERVATION PLAN, CENTRAL AND COASTAL SUBREGION (1996), document available at http://www.naturereserveoc.org/documents.htm. Although this situation does not precisely mirror the relationship between the CVP and SWP and their contractors, it does serve as precedent for creation of an HCP/NCCP that includes both land and resource management agencies and public/private land and resource users as incidental take permit holders.

Finally, it makes sense for the CVP and SWP contractors to seek the protections of the incidental take permits governing operation of the facilities authorized by the BDCP, as it is their uses of project water that would potentially violate the federal and state take prohibitions. The contractors thus would benefit both from the security provided by the incidental take permits and from participation in the decisions that would shape implementation and compliance with the terms and conditions limiting coordinated CVP/SWP operations set forth in the BDCP. Concomitantly, it is in the fish and wildlife agencies' interest to have the contractors participate as permittees so that disputes between the contractors and USBR and DWR as project operators may be resolved within the forum of the Authorized Entity Group, rather than outside the purview and procedures of the BDCP. Under these circumstances, we believe that it is likely that the courts would defer to the fish and wildlife agencies' reasonable interpretation of the statutes as authorizing the grant of incidental take permits to the CVP and SWP contractors. *See Chevron U.S.A. v. Natural Resources Defense Council,* 467 U. S. 837 (1984); *American Coatings Ass'n. v. South Coast Air Quality Dist.*, 54 Cal.4th 446 (2012).

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SUSTAINABILITY FROM THE GROUND UP
GROUNDWATER MANAGEMENT IN CALIFORNIA
– A FRAMEWORK –

APRIL 2011

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Foreword

In 2009, California lawmakers passed historic legislation that marked an important step toward improving the state's water supply reliability and restoring the Sacramento-San Joaquin Delta ecosystem. A critical challenge to achieving the goals of the legislative package is providing more effective management of groundwater resources at a time when California's reliance on its groundwater basins is growing due to a variety of short- and long-term factors.

The Association of California Water Agencies (ACWA) developed this Framework to describe current groundwater management efforts and identify proactive steps to advance sustainable groundwater management as part of the state's overall water management portfolio. ACWA believes the challenge of providing sustainable groundwater management must be met by local and regional agencies and not by centralized state regulation. Locally controlled groundwater management is effective because it is best able to respond to the particular circumstances of, and significant differences in, groundwater basins throughout the state. Local expertise and direct reliance on the resource ensures immediate response to problems and trends, and provides the strongest basis for collaborative regional approaches.

But as this Framework emphasizes, the job is far from done. While there are numerous case studies in successful management, efforts must be expanded in many parts of the state to achieve sustainable outcomes.

ACWA members are not daunted by the challenge. The actions and policy recommendations outlined in this document reflect the on-the-ground experience of experts involved in managing groundwater in every region of California and in a variety of geographic and hydrologic settings. Implementing these actions will help empower local agencies to strengthen their management efforts and contribute to the state's overall need for sustainable groundwater management, today and into the future.

To be successful, sustainable groundwater management must be accomplished in the context of a comprehensive solution that includes conveyance improvements in the Delta, investments in additional surface storage and groundwater storage to meet the co-equal goals, and massive investments in local water resources development.

ACWA members are prepared to step up to the challenge of providing sustainable groundwater management. We stand ready to work with policy makers and water managers to carry out actions and initiatives to promote more effective local groundwater management as part of a comprehensive solution.

Paul Kelley

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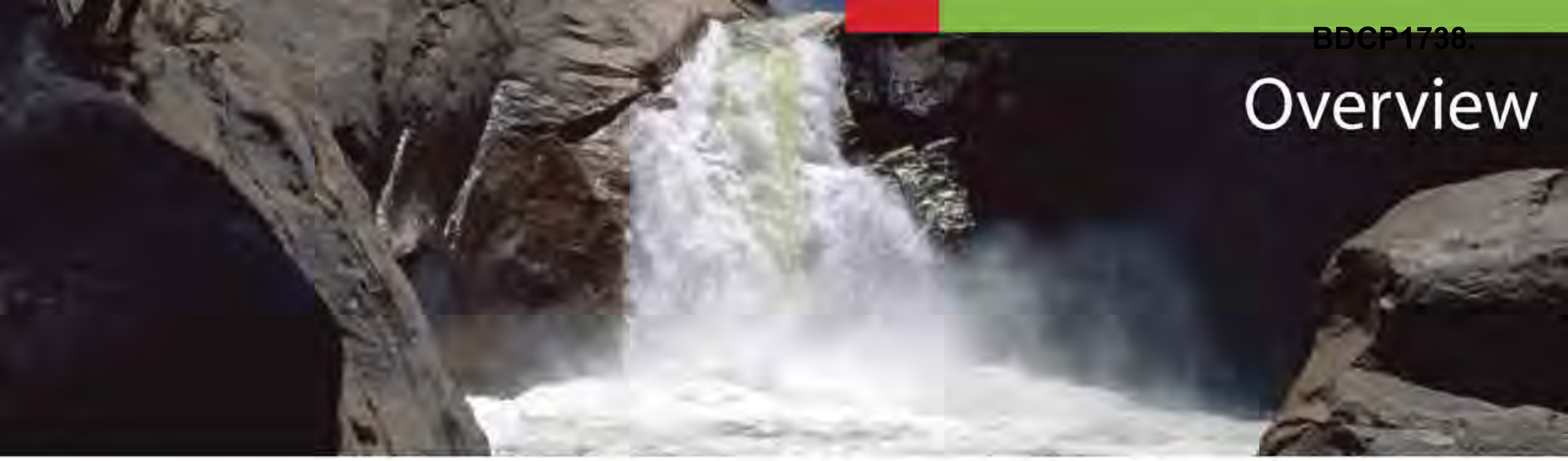

Overview

Groundwater has long been an integral part of California's water supply. Today, it has an even more critical role to play as the state grapples with significant water supply challenges.

California's water management system is arguably among the most complex and innovative in the world. Massive amounts of water are captured, stored and delivered through a combination of man-made and natural features to serve urban, agricultural and environmental needs.

Groundwater was widespread and abundant at the beginning of the 20th century. Its extensive availability contributed to large-scale agricultural and urban growth, which in turn steadily increased demand for and dependence on the resource. Effective management quickly became critical to protecting the future availability and quality of California's groundwater supplies. While many strategies have been implemented over the years to address groundwater management challenges, some are falling short today and require modernization.

Though California does not have a formal state-administered system of regulating and permitting groundwater use, it does have a long history of managing groundwater resources through locally controlled programs developed and refined over the past century.

Many of these programs have been very effective in addressing the state's most difficult groundwater management problems over the years. However, the array of challenges on the horizon will demand even more of local agencies and require a greater commitment to ensuring that local decisions and management contribute to statewide water policy goals.

The current state of California's groundwater should not be considered in isolation since it is largely reflective of broader water management concerns in the state. It has become increasingly clear in recent years that California's aging water supply and management infrastructure can no longer reliably meet the economic and environmental needs of the state. This is readily apparent in the Sacramento-San Joaquin Delta and elsewhere where challenges associated with population growth, drought, climate change, unmanaged groundwater overdraft and environmental concerns await resolution. The growing uncertainty of surface water supplies due to these and other factors has triggered greater reliance on groundwater as a principal or supplemental supply for urban, agricultural and environmental uses (e.g. wildlife refuges). It has also focused attention on groundwater basins as a potential storage solution.

The shift toward greater reliance on groundwater has magnified long-term risks to the quality and quantity of water available from California's groundwater basins. While Californians have relied on groundwater resources to varying degrees over the years, ACWA strongly believes today's growing dependence – intensified by both cyclical and long-term factors – will continue to stress California's groundwater basins unless proactive steps are taken at the local and regional level.

The California Legislature took an important step toward addressing the state's water challenges with passage of comprehensive water legislation in 2009. In addition to an $11.14 billion water bond now targeted for the November 2012 ballot and policy bills addressing Delta governance, water conservation, and water diversion and use, the package included new requirements for groundwater elevation monitoring to help track seasonal and long-term trends in groundwater basins.

ACWA developed this Framework to complement that legislation and advance the dialog on sustainable groundwater management. Produced by a task force of local groundwater managers from throughout the state, the Framework has four main purposes:

1. To define "sustainability" in terms that promote effective groundwater basin management;
2. To describe the current state of groundwater management in California, including an increasing number of successful local and regional management and conjunctive use programs, to provide an accurate and comprehensive foundation on which the public, policy makers and other stakeholders may make informed decisions;
3. To articulate groundwater management practices to address current and future challenges in California groundwater management; and
4. To identify specific policy development needs and recommend ways to enhance accountability, transparency, and the efficacy of sustainable groundwater management in California and its appropriate integration as a critical part of California's overall water management planning portfolio.

As evidenced by effective local and regional programs highlighted in this Framework, (see map, page 22), existing mechanisms for managing groundwater basins are providing an excellent foundation for sustainable management now and into the future. These examples, along with many other programs throughout the state, have generated impressive results and should be utilized as models for other agencies to help achieve the goal of sustainable groundwater management in California.

Locally controlled groundwater management is effective because local and regional entities are the most knowledgeable about their local basins and tend to be the first to notice changes or problems. They are also best suited to address issues unique to their region, including the implementation of proactive plans and actions to meet current and future groundwater needs.

Groundwater management plans developed under AB 3030, SB 1938 and the Integrated Regional Water Management Planning Act offer prime opportunities to enhance effective management and incorporate strategies that can help address the potential consequences of a large-scale shift to groundwater, whether cyclical or permanent. Doing so will also improve coordination and collaboration with state agencies as elevation data is collected pursuant to the new requirements of SBX7 6, enacted as part of the 2009 comprehensive legislative water package.

ACWA believes the state Legislature should encourage and support local management policies that appropriately reflect California's geographic and hydrologic diversity rather than institute a state-administered centralized control structure for regulating or permitting the use of groundwater. Statewide permitting and regulation would undermine the effectiveness of existing and planned local investments and would be counterproductive because it would not account for the significant differences in California groundwater basins throughout the state.

The Legislature should focus instead on incentivizing the development and implementation of the best practices outlined in this Framework. Recommendations for doing so are outlined beginning on page 29.

Ultimately, for sustainable groundwater management to succeed, California must invest in improvements to its water storage and conveyance infrastructure to optimize both surface and groundwater supplies. Such investments are critical if conjunctive use and groundwater banking are to realize their full potential as effective strategies to meet California's future demands, both economic and environmental. These investments must complement an ongoing commitment to expanded water use efficiency and water reuse.

ACWA believes that with the actions and policy modifications recommended in this Framework, local agencies can provide sustainable groundwater management, to the benefit of California, without the addition of new layers of state bureaucracy or regulation.

In addition to this Framework, ACWA has adopted Groundwater Management Policy Principles to provide further guidance and recommendations for sustainable management of the state's groundwater resources. The principles can be found on page 32. The Framework and the principles together provide a solid foundation for achieving groundwater management goals in California, and an effective basis for collaboration among the water and environmental communities, agriculture, business and labor leaders, and state and local governments.

Defining Sustainability

Sustainability has emerged as an important principle in natural resources management in recent years. ACWA has adopted policy principles that identify environmental and economic sustainability as co-equal priorities for water management in California.

In the context of groundwater, ACWA defines sustainability as actively managing the resource at the local level in a way that satisfies the needs of both the environment and the economy while ensuring the continued health of the basin. Given the importance of groundwater to California's water supply, sustainable management of the state's groundwater resources is essential to ensuring a reliable water supply and a healthy environment – both today and for generations of Californians to come.

The United States Geological Survey characterizes groundwater sustainability as the "development and use of groundwater in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences."[1]

Inherent in that definition as applied is the long-term protection and maintenance of both groundwater quantity and quality. As evidenced by effective local and regional programs throughout the state, managing groundwater basins to achieve sustainability has many benefits, including:

- More reliable surface and groundwater resources
- Increased opportunities for conjunctive use and recharge projects
- Environmental health / stability
- Drought mitigation
- Water quality improvements
- More effective land use planning and management
- Reduced energy costs associated with pumping

On the other hand, the lack of effective groundwater management contributes no such benefits and has led to the further decline of groundwater resources in certain areas of California. Unacceptable consequences include depletion of existing groundwater supplies, land subsidence, water quality degradation and environmental damage.

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[1] Alley, W.M., Reilly, T.E., and Franke, O.L. (1999). *Sustainability of Ground-Water Resources:* U.S. Geological Survey Circular 1186.

Groundwater Management Today

In California, groundwater management generally refers to a locally developed and controlled program that integrates groundwater protection, recharge, extraction and monitoring to achieve the long-term sustainability of the resource. Since groundwater basins vary greatly around the state, local control and supervision allow for the most effective and careful management of the resource. One size does not fit all when it comes to groundwater management.

California is known for its diverse ecosystems, topography and geology and for its highly variable water resources. With more than 38 million people and a land area of 100 million acres, California is the most populous state and the third-largest geographically in the country. It is also the most productive agricultural state, producing over half the fruits, nuts and vegetables in the nation.

In 2000, an average water year, California cities and suburbs used about 8.9 million acre-feet (MAF) of water. California agriculture irrigated 9.6 million acres of cropland (includes multi-cropping) using roughly 34 MAF of applied water. Dedicated environmental uses of water, including in-stream flows, wild and scenic flows, required Delta outflow, and managed wetlands, exceeded 39 MAF.[2]

In an average year (based on 1998-2005 data), groundwater resources supply about 35 percent of California's urban, agricultural and managed wetlands water demands (about 15 million acre-feet per year).[3] In dry years, this percentage increases to 40 percent or higher statewide and as high as 60 percent or more in some regions. Nearly half of California's drinking water supply comes from groundwater.

In addition to contributing essential water supplies, the state's groundwater basins provide significant water storage capacity. This storage capability is important in and of itself, but when used in conjunction with surface water storage it can go a long way toward meeting local and regional needs for greater flexibility, increased water supply reliability and improved water quality. This potential is limited, however, by current regulatory and infrastructure constraints on groundwater recharge and extractions. Optimizing large-scale conjunctive use programs will require investments in both surface and groundwater storage.

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[2] California Department of Water Resources. *California Water Plan Update 2009:* v1c4, pp 4-12, 4-21.

[3] California Department of Water Resources. *California Water Plan Update 2009:* v2c8, p 8-10.

APPLIED WATER VS. CONSUMPTIVE USE

According to the California Department of Water Resources, applied water is the amount of water from any source needed to meet the demand for beneficial use by the user. It includes consumptive use, reuse, and outflows. Consumptive use is a quantity of applied water that is not available for immediate or economical reuse. It includes water that evaporates, transpires, or is incorporated into products, plant tissue, or animal tissue. Consumptively used water is removed from available supplies without return to a water resource system (uses such as manufacturing, agriculture, landscaping, food preparation, and in the case of Colorado River water, water that is not returned to the river.)*

*DWR California Water Plan Update 2005 http://www.waterplan.water.ca.gov/docs/cwpu2005/vol2/v2glossary.pdf

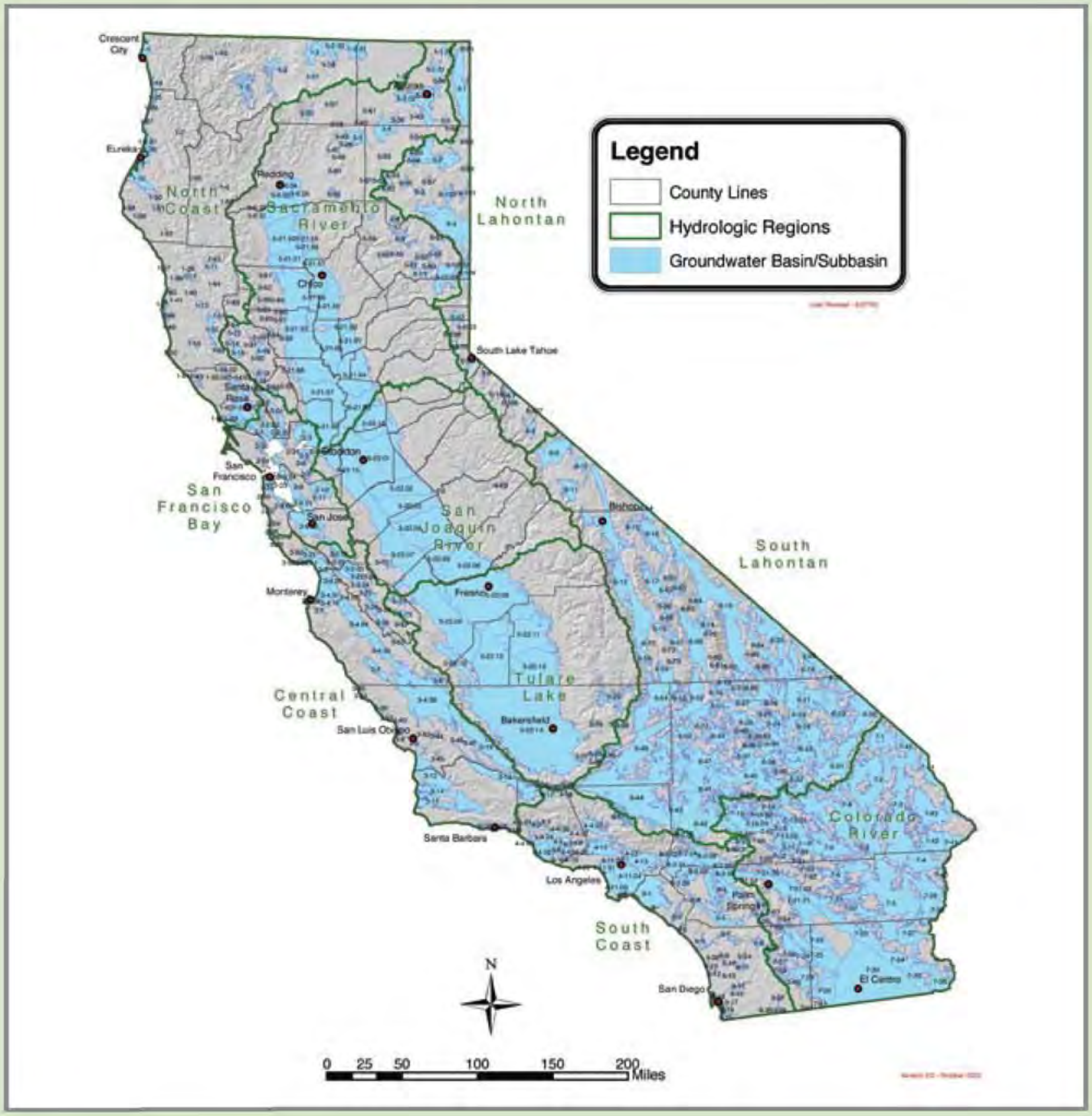
WHERE DOES GROUNDWATER COME FROM?

Much of the water from snowmelt and rain that flows into surface water formations (e.g. creeks, streams, rivers, ponds) percolates into the ground and becomes groundwater. Groundwater can be thousands of years old, but most of the groundwater typically used in California today is extracted a few years to a few decades after its original percolation.

Groundwater is found in two main types of geologic settings in California. The vast majority of groundwater in the state is stored in alluvial basins, which are composed of sediments such as gravel, sand, silt or clay and cover nearly 40 percent of the geographic area of the state. Alluvial basins account for all 515 basins and sub-basins identified in DWR's Bulletin 118. (http://www.water.ca.gov/pubs/groundwater/bulletin_118)

However, groundwater is also stored and extracted from fractured bedrock or sandstone. About 20 percent of the state's municipal supply wells are located in this type of formation, with prime examples found in the Sierra Nevada and the Coast Ranges.

Groundwater Basins in California



Water Supply Infrastructure: Key to Meeting Needs

Precipitation in California varies widely—from place to place, from season to season, and from year to year. Wet years can bring the threat of floods, while dry years can reduce available water supplies and require the temporary draw-down of stored water. This unpredictable hydrology affects not only the amount of surface water available in a given year but also the amount of groundwater available for extraction and use.

The state's water storage and delivery infrastructure was designed to address that unpredictability, protecting communities from floods and capturing winter precipitation and spring snowmelt for strategic delivery in the drier summer and fall months. The system also contributes to effective groundwater management by providing surface water to augment local supply sources and alleviate pressure on groundwater basins.

California's two largest water delivery systems are the State Water Project (SWP) and the federal Central Valley Project (CVP). The SWP, operated by the California Department of Water Resources, delivers water to 25 million Californians and 755,000 acres of irrigated farmland. The CVP, operated by the United States Bureau of Reclamation, provides water for more than 3 million acres of farmland and drinking water to nearly 2 million consumers.

All told, California has nearly 200 surface storage reservoirs with a capacity of 10,000 acre-feet or more, for a combined storage capacity of more than 41 MAF. In addition, there are many other reservoirs smaller than 10,000 acre-feet that are used to manage water for a wide range of uses.

Given the state's highly variable hydrology, surface and groundwater storage facilities are critical to supplying cities, farms, businesses and the environment with adequate water year-round. They are particularly effective when used in concert with each other to make maximum use of water when it's available and store it for use in dry times.

Conjunctive Use: A Critical Part of Sustainable Management

Conjunctive use or management refers to the coordinated and planned use of both surface water and groundwater resources to maximize the availability and reliability of water supplies in a region to meet various management objectives. Since surface water and groundwater resources can differ significantly in their availability, quality, cost and other characteristics, managing both resources together, rather than in isolation from each other, allows water managers to use the advantages of each for maximum benefit.

WHAT IS GROUNDWATER BANKING?

Groundwater banking is a water management tool designed to increase water supply reliability. By using dewatered aquifer space to store water during wet years (when there is abundant rainfall and surplus water available), water can be pumped and used during dry years (when there is little rainfall and no surplus water).

Groundwater banking is accomplished two ways: through in-lieu and direct recharge. In-lieu recharge is storing water by utilizing surface water "in-lieu" of pumping groundwater, thereby storing an equal amount in the groundwater basin. Direct recharge is storing water by allowing it to percolate directly to storage in the groundwater basin.*

*Definition courtesy of Semitropic Water Storage District

CONJUNCTIVE MANAGEMENT OF LOCAL AND IMPORTED WATER SUPPLIES: THE KEY TO A SUSTAINABLE SILICON VALLEY

Graphic courtesy of Santa Clara Valley Water District

The Santa Clara Valley Water District has a long record of conjunctive water management. Established in the late 1920s to address groundwater overdraft and subsidence, the district constructed seven dams by 1935 to impound surface water for recharge into percolation facilities. As the graphic illustrates, the post-war boom brought increased demands for water and the return of unsustainable declines in groundwater elevation. Surface reservoir capacity was quadrupled by constructing four additional reservoirs in the 1950s. In 1965, the district began importing surface water from the State Water Project. Groundwater levels began to recover and the rate of subsidence slowed significantly. The rise of Silicon Valley brought increased demands again, and the district added Central Valley Project deliveries to its supply portfolio in the late 1980s. By the mid-1990s groundwater elevations had returned to levels seen at the turn of the 20th century.

Conjunctive use has been practiced for decades in California. In general, conjunctive use programs take advantage of available groundwater storage capacity to “bank” or store surface water through natural and / or artificial recharge for later extraction and use. In many areas, there is tremendous potential to enhance local supplies even further by utilizing storm flows and recycled water with appropriate safeguards to augment groundwater recharge.

Well-planned conjunctive use programs not only enhance local and regional water supply reliability, but can also provide other benefits such as enhanced flood management, improved environmental water management, reduced reliance on the Delta to meet future water supply needs, and water quality improvements.

Conjunctive use projects require investments in surface storage, conveyance systems, recharge and extraction facilities, and management of groundwater basins. Conveyance systems may include lined and / or unlined canals, pipelines, and streams. Recharge options include direct spreading and infiltration in artificial ponds, injection via wells, and induced natural recharge in natural systems. In the strategy known as in-lieu recharge, surface water can be provided to users who normally use groundwater to allow supplies to stay in groundwater basins.

Groundwater may be extracted later for direct use, for pumping back to conveyance systems, or for surface water exchange.

KEY WATER PROJECTS IN CALIFORNIA

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WHAT ARE SOME OF THE SOURCES FOR CONJUNCTIVE USE PROJECTS?

Imported water – Water that is transferred across hydrologic region boundaries from one agency to another. Many parts of the state receive imported water from the State Water Project and Central Valley Project.

Local surface water – Direct deliveries of water from stream flows, as well as water supplies from local storage facilities.

Recycled water – Municipal, industrial, or agricultural wastewater that is treated to produce water that can be reused.

Reclaimed water – Treated water where the inflow water supply is polluted, contaminated, or otherwise tainted.

Desalinated water – Water that has been treated to remove salt for beneficial use. Source water can be brackish (low salinity) or seawater.

Stormwater (runoff) – Water that collects during a precipitation event and may carry pollutants to water courses, causing degradation.*

*For more information, please see Bulletin 160 Water Plan Update 2009 Glossary (http://www.waterplan.water.ca.gov/docs/cwpu2009/0310final/v4c01ag_cwp2009.pdf)

The Current Regulatory Landscape

California is often criticized for being one of the only Western states without a formal state-administered system of regulating and permitting groundwater use. But while it is true there is no *centralized* system to regulate the use of groundwater, California has developed and refined an effective system of locally controlled groundwater management over the past century.

As noted by the California Legislative Analyst's Office[4], the current system has been successful in addressing the state's most difficult groundwater management problems over the years. The growing list of challenges on the horizon, however, will demand more of local agencies and require a greater commitment to ensuring that local decisions and management contribute to achieving statewide water policy goals.

To that end, ACWA is confident that, with certain modifications recommended in this Framework, local agencies can provide sustainable groundwater management for the benefit of California without the addition of new layers of state bureaucracy or regulation.

Basic Legal Principles Set Foundation

As a general rule, landowners in California are entitled to pump and use a reasonable amount of groundwater from a basin underlying their land. Under the doctrine known as "correlative rights," landowners overlying a common source of groundwater are limited to using a reasonable share, typically based on the amount of overlying land owned by each and the physical condition of the basin. When there is insufficient water to meet the demands of overlying landowners, those users are expected to reduce their demands correlatively to bring their groundwater extractions within the safe yield of the basin and prevent overdraft.

Entities other than overlying users, such as cities, may be entitled to "appropriate" water from the basin for use as a municipal supply when water surplus to the needs of overlying users is available. Unless otherwise prescribed, appropriators must curtail their use when there is no surplus.

As the above paragraphs suggest, the interrelated concepts of "safe yield," "surplus" and "overdraft" are central elements in the legal landscape addressing California groundwater. As defined by the California Supreme Court in the landmark *Los Angeles v. San Fernando* case in 1975, "safe yield" refers to "the maximum quantity of water which can be withdrawn annually from a groundwater supply under a given set of conditions without causing an undesirable result." The phrase "undesirable result" is understood to refer to "a gradual lowering of the groundwater levels resulting eventually in depletion of the supply." "Surplus" refers to "the amount of water in a groundwater basin in excess of safe yield." *City of Los Angeles v. City of San Fernando* (1975) 14 Cal.3d at 278.

The *San Fernando* court also clarified that an overdraft occurs only when extractions exceed safe yield plus "temporary surplus," the latter term defined as the amount of water that can be pumped from a basin to provide storage space for surface water that would otherwise be lost during wet years if it could not be stored in the basin. *Id.* at 279.

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[4] California Legislative Analyst's Office. 2010. *Liquid Assets: Improving Management of the State's Groundwater Resources.* (http://www.lao.ca.gov/laoapp/PubDetails.aspx?id=2242)

Recognizing Interplay Between Surface Water and Groundwater

Though surface water and groundwater are often interconnected from a hydrologic perspective, they are generally managed and regulated through separate legal regimes in California. The Legislative Analyst's Office and others have called for California's groundwater law to be "modernized" to better reflect the well-established physical connection between groundwater and surface water in many areas.

That recommendation fails to consider, however, that California has a long and reasonably well-developed history of successfully integrating the use of surface water and groundwater, despite the existence of two different legal regimes. Though this "dual system" may not always appear neat and orderly, case law is sufficiently well-developed to suggest that California courts are fully aware of the interplay between surface water and groundwater in specific instances and have crafted legal doctrines to address those hydrologic realities.

A LOOK AT LEGAL CASES OVER THE YEARS

Under California law, water is characterized as being surface water or groundwater. Groundwater is further classified as either a subterranean stream or as percolating groundwater. Surface water and groundwater classified as a subterranean stream are subject to the permitting authority of the State Water Resources Control Board, while groundwater classified as percolating groundwater is not subject to that authority.

In areas where there is a hydrologic connection between groundwater and surface water resources, a number of early cases established the legal rules for interconnected surface water and groundwater systems. These rules form the foundation of groundwater management today.

Potential Interference by Groundwater Pumpers with Surface Water Rights

Case Information	Result
City of Los Angeles v. Hunter (1909) 156 Cal. 603, 607; *McClintock v. Hudson* (1903) 141 Cal. 275, 278; *Los Angeles v. Pomeroy* (1899) 124 Cal. 597, 624.	Found that a user of percolating groundwater may diminish flows in a surface stream only if the groundwater is put to reasonable use on lands overlying the groundwater basin.
Hudson v. Dailey (1909) 156 Cal. 617, 624-627.	Virtually ignores the distinction between riparian rights to surface water and correlative rights to groundwater in finding a right to extract groundwater for use on overlying lands despite impacts on downstream riparians and downgradient overlying pumpers.
Barton Land & Water Co. v. Crafton Water Co. (1915) 171 Cal. 89, 94-95.	Owner of lands overlying a subterranean stream cannot extract water from that stream so as to have an adverse impact on surface water diverters.

Potential Interference by Surface Water Diverters with Groundwater Rights

Case Information	Result
Miller v. Bay Cities Water Co. (1910) 157 Cal. 256, 276-279 (overruled on other grounds in *City of Lodi v. East Bay Municipal District* (1936) 7 Cal.2d 316, 338-339).	California Supreme Court decision that articulated a broad standard protecting the owner of percolating groundwater from surface appropriations of water on non-riparian lands
United States v. Fallbrook Pub. Util. Dist. (S.D. Cal. 1958) 165 F.Supp. 806, 847 (citing *McClintock*, 141 Cal. at 281; *Hudson*, 156 Cal. at 628).	Federal district court decision that found riparian and overlying rights are treated as extracting water from one common source and so have joint rights to reasonable shares of the resource.

Challenges to Sustainable Groundwater Management

To advance sustainable groundwater management, it is essential to understand the growing list of challenges related to California's groundwater basins.

Addressing these challenges will require comprehensive efforts by local agencies individually and within regional partnerships to develop and implement sustainable groundwater management practices. This brief overview describes a number of factors confounding the management of California's groundwater resources.

Declining Sacramento-San Joaquin Delta

The Sacramento-San Joaquin Delta is the hub of California's two main water delivery systems – the State Water Project and the federal Central Valley Project. Court-ordered restrictions to protect species have significantly reduced deliveries from these projects in recent years. This reduction in surface water supplies has hampered conjunctive use projects in some parts of the state and highlighted the need for more sustainable groundwater management as urban, agricultural and environmental users have turned to local groundwater resources as a substitute for increasingly unreliable SWP and CVP deliveries.

Periodic, Inevitable Droughts

The southwestern United States, including California, is prone to periodic droughts. Most recently, three consecutive dry years from 2006-2009 resulted in some of the driest conditions in decades and reduced water storage in key reservoirs to record lows. Regulatory restrictions on SWP and CVP deliveries magnified the impacts of this natural drought.

Prolonged drought has multiple effects on groundwater resources and management. The lack of available surface water can place additional demands on groundwater basins. Less surface water also means less water available for groundwater recharge. If groundwater levels drop as a result of increased demand or reduced recharge, there are additional energy costs to pump groundwater and greater potential for overdraft conditions. Further, the strategic value of conjunctive use projects that rely on surface water reliability can be undermined.

Changing Climate

Climate change will exacerbate the existing water management challenges facing California, including those affecting groundwater resources. Possible consequences include more frequent drought periods, reduced snowpack in the Sierra Nevada, increased flooding intensity as well as impacts to the operation of the state's surface storage facilities.[5] Higher temperatures, particularly in inland areas, could lead to increased demands on water supplies for urban, agricultural and environmental uses.

Changes in rainfall patterns could also result in faster local runoff and reduced natural groundwater recharge. Collectively, these impacts could result in less reliable water supplies and an overall increase in the demand for groundwater supplies.

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[5] ACWA Policy Principles on Climate Change. March 2010.

"HIGHER HIGHS, LOWER LOWS"

Based upon historical data and modeling, DWR projects that the Sierra snowpack will decline by 25 percent to 40 percent from its historic average by 2050. Climate change is also anticipated to bring warmer storms that result in less snowfall at lower elevations, reducing the total snowpack.* These storm events will, however, increase peak flows and affect the length of the recharge and recovery cycle of reservoirs that is critical to effective conjunctive use projects.

* California Department of Water Resources. *Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water.* October 2008.

Unmanaged Overdraft and Subsidence

Overdraft is defined as the condition of a groundwater basin when the amount of water withdrawn by pumping over the long term exceeds the amount of water that recharges the basin, either through natural or artificial methods. A basin in overdraft tends to not fully recover, even in wet years. While the occasional extraction of groundwater in amounts greater than annual recharge can be part of an effective groundwater management plan, unmanaged or excessive extractions can result in land subsidence, water quality degradation, and environmental impacts.

Protracted Drought on the Colorado River

The Colorado River is a key source of water for seven states and Mexico, providing water for some 30 million people to drink and meet household needs, irrigate crops and urban landscapes, operate businesses and replenish groundwater basins. California's annual allocation is 4.4 MAF for irrigation and domestic uses. The Colorado River Basin is in the midst of a multi-year drought that has reduced reservoir storage to record-low levels. These conditions are affecting the reliability of Colorado River supplies for conjunctive use projects and other beneficial uses throughout Southern California. Climate change is expected to further diminish the reliability of deliveries to California.

Aging System and Maintenance Backlog

California has not made significant investments in its backbone water storage and delivery systems, the SWP and CVP, in more than 40 years. In addition, several key components of the projects as originally planned were never built. Constructed when the state's population was just 18 million, the projects are struggling to meet the needs of 38 million Californians today. They also lack the flexibility to meet 21st century demands for both ecosystem health and water supply reliability. These aging facilities also suffer from a backlog of maintenance and repair needs arising from budget and contracting constraints.

Further complicating the effective maintenance of the state's water infrastructure is the growing number of issues related to an aging workforce. It is becoming increasingly difficult to secure professionals for policy and technical positions (such as engineers and water treatment operators), particularly those with extensive experience in California's water industry. As those individuals with expertise begin to retire en masse or find employment elsewhere, effective operation of the state's complex water infrastructure will further erode.

As a result of the increasing physical and workforce limitations, contractual and historic water delivery expectations are not being met and the existing facilities have neither the capacity nor flexibility to adapt to the approaching challenges presented by climate change. The deterioration of the delivery capabilities and reliability of this surface water infrastructure has resulted in, and will continue to contribute to, reductions in the amount of supply available for effective recharge and increasing demands for already-stressed groundwater resources.

At the local and regional level, efforts to maintain and upgrade facilities can be constrained by factors such as Propositions 218, which limits the ability of local agencies to raise rates and fees for a variety of projects and purposes. In addition, the practice of restricting bond funds solely for new construction and not for retrofitting and major maintenance needs can undermine past investments by allowing the foundation upon which they rely to crumble.

Groundwater Quality Degradation

Groundwater quality degradation has become a significant challenge for agencies that manage groundwater. Though groundwater quality can be affected by many factors, some of the most significant threats include chemical contaminants, both naturally occurring and man-made, salinity (including seawater intrusion), landfills and other hazardous waste sites. When groundwater quality is compromised, it may become unsafe for consumption or other uses and it can, without remediation, render the basin unfit for conjunctive use and artificial recharge projects.

Efforts to remediate groundwater contamination can be complicated by a number of issues. Under current law, local agencies that wish to initiate a remediation effort can face numerous disincentives that can hinder or even prevent a proactive approach. Difficulties related to liability, water quality standards, anti-degradation versus non-degradation concerns, assignment of costs and other factors are impediments to clean-up efforts.

Limited Data Collection, Interpretation and Use

In many areas, the lack of a comprehensive approach to systematically managing data on California's groundwater resources is a considerable challenge to sustainable groundwater development. Due to inadequate funding, a comprehensive assessment of groundwater level trends in California's groundwater basins has not been conducted since 1980. While some data is collected through ongoing efforts such as the Groundwater Level and Quality Monitoring Program (DWR), the Groundwater Ambient Monitoring and Assessment (GAMA) Program (administered by the U.S. Geological Survey under contract to the State Water Resources Control Board), and the U.S. Geological Survey Groundwater Information Program, these initiatives are weakened by their limited geographic scope. DWR and the

HOW DOES LAND SUBSIDENCE OCCUR?

Land subsidence is the gradual settling or sudden sinking of the Earth's surface due to changes that take place underground. This movement of earth can be the result of many factors, including groundwater extraction. In some types of groundwater basins, water that is pumped to the surface is drawn from spaces between sand and gravel. In addition, layers of clay can contain large amounts of water, and water pressure in the surrounding aquifer keeps the clay particles slightly apart from each other. When the water pressure in such a basin drops due to extensive pumping, the clay particles are pushed together by the weight of the overlying sediments, which is no longer in equilibrium with the (now lower) water pressure. As clay particles are pressed together for lack of water pressure, water drains out of the clay and the clay layers become compressed (thinner).

The effect of thinner clay layers is seen as a lowering of the land surface – sometimes as much as 20 or 30 feet over the course of a few decades. The lowering of land surface elevation from this process is permanent. Effective groundwater management utilizes the storage capabilities of groundwater basins while preventing significant subsidence from occurring. More information can be found at http://www.water.ca.gov/groundwater/well_info_and_other/land_subsidence.cfm, http://geochange.er.usgs.gov/sw/changes/anthropogenic/subside/.

SWRCB do not adequately coordinate their statewide monitoring efforts. This lack of comprehensive data management will continue to hinder the ability of local and regional agencies to optimize the use of California's groundwater resources.

Small System Vulnerability

Small community water systems, including many that serve disadvantaged populations, can face unique management challenges not shared by their larger counterparts. Such systems that are dependent on groundwater and / or private wells are especially vulnerable to drought and the effects of climate change because they are typically located in isolated areas with few opportunities for interconnections with other systems, water transfers, or emergency relief. This can also make it more challenging to develop successful conjunctive use programs or implement costly water quality treatment technologies.

Fragmented Regulations

California has a multifaceted and complex regulatory structure. Numerous agencies have jurisdiction over various aspects of groundwater recharge and banking projects, particularly those involving underground storage supplements (USS) and aquifer storage and recovery (ASR). Regulations governing these projects tend to be fragmented, duplicative or unnecessarily complicated. Often-conflicting regulatory requirements affecting the same basin or water supply can also slow or even stall progress on critical projects.

Mounting Environmental Requirements

In addition to a complicated regulatory landscape, local water agencies must adhere to an array of environmental statutes as they plan, develop and operate projects. The California Environmental Quality Act (CEQA), for example, adds numerous layers and requirements that can be a hurdle to moving projects forward. Depending on how they are implemented, the state and federal Endangered Species Acts can also affect development and operation of projects, sometimes at great cost to water supplies. Loss of surface water supplies as a result of environmental regulations can result in greater short-term reliance on groundwater, often with long-term ramifications.

Land Use Decisions and Population Growth

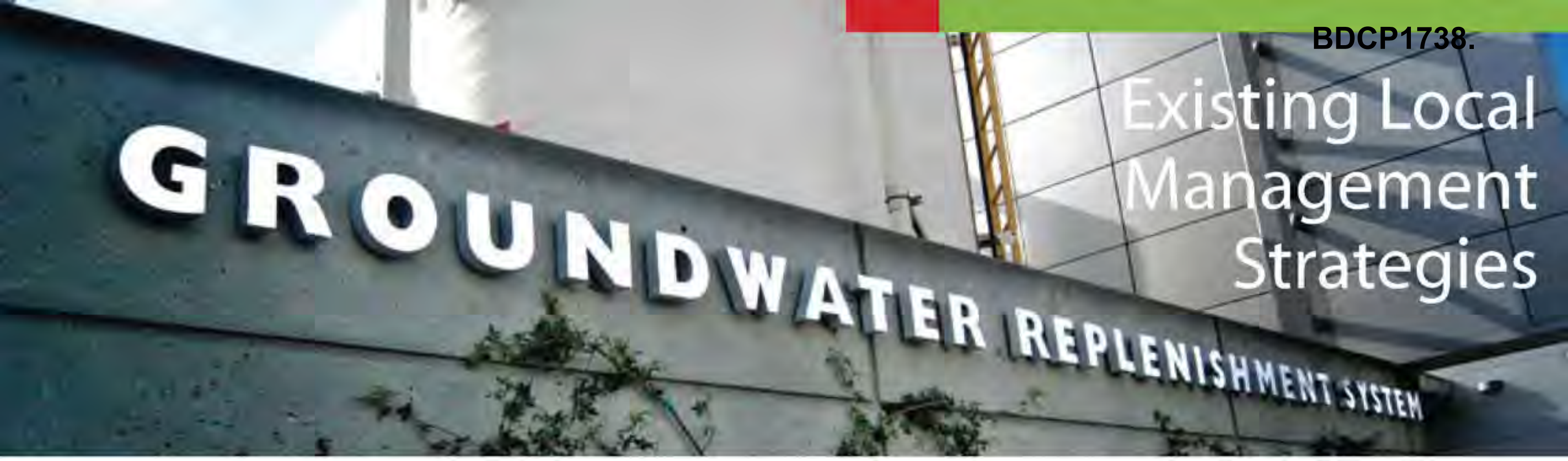
Population growth and commercial development continue to put pressure on resources throughout California. As competition increases for a limited amount of developable land, the need to retain adequate groundwater recharge capability is often overlooked in decisions affecting land use. Activities such as paving and development change the absorption capacity of land, thereby reducing opportunities for natural recharge. In some watershed areas, forestry practices affect in-stream recharge by contributing to siltation, which blocks the absorption capability of creek and river bottoms.

Land use policies and regulations that fail to consider and protect natural and artificial recharge and extraction capabilities create long-term challenges for successful sustainable groundwater management, including permanent reductions in permeable acreage, water quality degradation and land subsidence. Such policies can also exacerbate problems associated with management of stormwater runoff.

CONJUNCTIVE USE OPERATIONS AND "OVERDRAFT"

An increasingly common practice in California is to operate a groundwater basin in conjunction with available surface water supplies on a local or regional level. The practice involves exercising the basin, a process that causes the groundwater level to go up and down with wet and dry annual and periodic cycles. During the wet season and during wetter years, surface water is relied on more and the groundwater basin is recharged with surplus surface water, from local and / or imported sources, resulting in groundwater level increases. Such recharge occurs through direct means via spreading basins or in-lieu via surface deliveries that otherwise offset groundwater pumping. During dry years, when less surface water is available, groundwater is relied on more, drawing the groundwater levels down.

In the event of a periodic drought lasting several years, when less surface water is available and groundwater is used more extensively to meet demands, groundwater level trends can sometimes decline quite dramatically without any notable recovery for a longer period of time. The groundwater level trend in a conjunctively managed basin over a period of several years during a drought may appear as long-term overdraft; however, some would refer to this as "managed overdraft" as the downward trend will be offset by recovery cycles in wetter periods utilizing the direct or in-lieu groundwater recharge methods.



Existing Local Management Strategies

California relies on a variety of mechanisms to promote the local control and management of groundwater resources. Since the earliest efforts to manage California's groundwater, the effectiveness and complexity of these strategies has continued to evolve with changing urban and environmental needs and conditions.

As previously noted, every groundwater basin in California presents unique physical and hydrogeological characteristics. In addition, each basin has unique beneficial uses dependent upon water quality, water rights, number and breadth of stakeholders, institutional type and complexity, and other features.[6]

Locally-controlled groundwater management is effective because local and regional entities are the most knowledgeable about their local basins and tend to be the first to notice changes or problems. They are also best suited to address issues unique to their region, including the implementation of proactive plans and actions to meet current and future groundwater needs.

Since local stakeholders and management agencies receive the direct benefits of sustainable management, they are more inclined to support investments in local infrastructure and water quality projects, which in turn leads to more consistent implementation of improvements. Local agencies are also in the best position to identify and assess the consequences of over-reliance on groundwater resources and to evaluate options for improved management. While a certain degree of coordination with the state is important, particularly with regard to data management and funding, one-size-fits-all mandates and uniform statewide protocols tend to be counterproductive because they do not recognize the significant differences in California groundwater basins.

Basic Management Mechanisms

As noted in the Department of Water Resources' California Groundwater Bulletin 118[7], there are three basic mechanisms available for managing groundwater resources in California. These mechanisms include: 1) management by local agencies under authority granted by state statute; 2) coordinated agreements and ordinances; and 3) court adjudications.

Local and regional agencies employ a variety of successful management strategies under these mechanisms, reflecting the diversity of the state's groundwater basins and the diverse beneficial uses of water from those basins. Examples can be found on pages 22 and 23. Financial support and incentives at the state and local levels have also contributed to the success of local and regional groundwater management plans. State policy makers can play a key role in promoting these efforts by providing consistent support and assistance through legislation and funding. Propositions 204, 13, 50 and 84 are examples of this constructive support.

Local Management under Authority Granted by State Statute

Many local water agencies are authorized by statute to institute and conduct some form of groundwater management. Agencies formed under the Water Replenishment District Act and the Water Conservation District Act, for example, are authorized to carry out groundwater replenishment programs and assess fees to pay for groundwater management programs.

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[6] California Department of Water Resources. *California's Groundwater, Bulletin 118 - Update 2003.* (http://www.water.ca.gov/groundwater/bulletin118/bulletin118update2003.cfm)

[7] California Department of Water Resources. *California's Groundwater, Bulletin 118 - Update 2003: Ch. 2.* (http://www.water.ca.gov/pubs/groundwater/bulletin_118/california%27s_groundwater__bulletin_118_-_update_2003_/bulletin118-chapter2.pdf)

FINANCIAL SUPPORT FOR LOCAL GROUNDWATER MANAGEMENT

The California Legislature and voters have approved several propositions that included funding for groundwater quality remediation or local and regional management. The following are the most recent and largest allocations:

The Safe, Clean, Reliable Water Supply Act of 1996 (Proposition 204)

This measure authorized the state to sell $995 million in general obligation bonds for the purposes of restoration and improvement of the Bay-Delta; wastewater treatment, water supply and conservation; and local flood control and prevention. Funds were included in Proposition 204 for a water conservation and groundwater recharge loan program ($30 million) and local water supply development and environmental mitigation ($25 million).

The Safe Drinking Water, Clean Water, Watershed Protection and Flood Protection Act of 2000 (Proposition 13)

Proposition 13 was a $1.97 billion general obligation bond with $230 million earmarked for groundwater programs. The act authorized $200 million for grants for feasibility studies, project design, and construction of conjunctive use facilities (Water Code, § 79170 et seq.) and $30 million in loans for local agency acquisition and construction of groundwater recharge facilities and feasibility study grants for projects potentially eligible for the loan program (Water Code, § 79161 et seq.).

Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (Proposition 50)

California voters approved the Water Security, Clean Drinking Water, Coastal and Beach Protection Act of 2002 (Proposition 50; Water Code, § 79500 et seq.), which provided for more than $3.4 billion in funding, subject to appropriation by the Legislature, for a number of land protection, water quality and water management activities. Proposition 50 provided $500 million for integrated regional water management, water management projects that will protect communities from drought, protect and improve water quality, and reduce dependence on imported water supplies.

The Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 (Proposition 84)

Proposition 84 authorized $5.488 billion in general obligation bonds to fund safe drinking water, water quality and supply, flood control, waterway and natural resource protection, water pollution and contamination control, state and local park improvements, public access to natural resources, and water conservation efforts. Within Proposition 84 is $60 million for projects that prevent or reduce groundwater contamination, and $1 billion for integrated regional water management (IRWM) planning and implementation.

*Note: The 2009 legislative package included an $11.14 billion water bond (set for the November 2012 ballot) with additional funding for groundwater activities. See page 28 for more on the package.

Currently, 13 local agencies throughout California have specific authority under special legislation to limit or regulate groundwater extraction.

AB 3030 Plans

The Groundwater Management Planning Act, commonly known as AB 3030, greatly expanded the number of local agencies with authority and responsibility over groundwater resources. The act, which became effective in January 1993, was aimed at encouraging more effective local management as an alternative to establishing a state-administered groundwater management structure. AB 3030 was developed by ACWA and its Groundwater Committee, partially in response to the U.S. Environmental Protection Agency's Comprehensive State Ground Water Protection Program (CSGWPP), which promoted comprehensive groundwater quality management on the state level with EPA providing proposed oversight and coordinated funding.

After the passage of AB 3030, many water agencies developed voluntary "3030" plans and significantly increased their involvement in groundwater management. As of 2003, more than 200 agencies have adopted an AB 3030 groundwater management plan.[8] This legislation was a big step forward in formalizing and supporting the local management of groundwater in California. Some plans prepared under its provisions, however, have suffered from little or no implementation, while others have focused primarily on limiting exports of groundwater to other regions, rather than incorporating all elements of a comprehensive management program.

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[8] California Department of Water Resources. *California's Groundwater, Bulletin 118 - Update 2003: Ch. 2.* (http://www.water.ca.gov/pubs/groundwater/bulletin_118/california%27s_groundwater__bulletin_118_-_update_2003_/bulletin118-chapter2.pdf)

SB 1938 Groundwater Management Programs

In 2002, the Legislature passed SB 1938. This statute provides additional direction and technical guidance to local agencies for developing groundwater management plans and requires the inclusion of basin management objectives relative to groundwater quantity and quality, subsidence and monitoring programs. SB 1938 also requires agencies to have a groundwater management plan that meets certain requirements in order to be eligible for any state grant or loan programs for groundwater projects.

Building upon the positive elements of AB 3030, SB 1938's passage strengthened the effectiveness of groundwater management plans in California. Many agencies have supplemented their existing plans by incorporating the bill's new provisions or are developing entirely new SB 1938 plans to not only sustain the resource but also to ensure eligibility for state grants or loans.

AB 3030 and SB 1938 plans have provided the basis for action and progress. Under the Local Groundwater Assistance Program (AB 303), DWR awarded nearly $28 million in grants between 2000 and 2005 to local agencies to conduct 128 projects involving groundwater management plans or related activities.[9]

DWR also distributed $205 million in funds from Proposition 13 to groundwater recharge and storage feasibility studies, pilot projects and construction projects between 2000 and 2004, with the total value of those efforts (when combined with leveraged local dollars) totaling over $1 billion. Primary benefits from these activities were enhanced groundwater management and improved water supply reliability, but there have been other benefits as well, including improved drinking water quality, groundwater protection, reduced wastewater discharges, dedicated environmental water and improved habitat / wetlands restoration. It is estimated that these projects provide an additional 300,000 acre-feet per year to local California water supplies.[10]

More recent water bond measures have also included funding to support local groundwater management programs. When distributed, that funding will assist local management entities to ensure further progress in the implementation of their plans.

Groundwater management plans developed under AB 3030 and SB 1938 are among the most effective and widely used management techniques in California. As noted, more than 200 plans have been implemented throughout the state. Entities implementing this type of management are also best prepared to work with state agencies as elevation data is collected pursuant to the new requirements of SBX7 6, enacted as part of the 2009 comprehensive legislative package on water. The comprehensive structure of AB 3030 and SB 1938 plans provides a vehicle to simultaneously provide effective management now and into the future while remaining focused on local hydrologic and economic conditions.

Integrated Regional Water Management Plans (IRWMPs)

Proposition 50's passage in 2002 provided additional grants and matching funding for local projects consistent with the new integrated regional water management plan (IRWMP) initiative. IRWMPs require various local entities to

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[9] California Department of Water Resources. *Local Groundwater Assistance Program Five-Year Report, 2000-2005.* (http://www.water.ca.gov/groundwater/docs/AB303_Finalized_050206.pdf)

[10] California Department of Water Resources. *2000-2004 Proposition 13 Groundwater Grants and Loans Program Summary.* (http://www.grantsloans.water.ca.gov/docs/prop13/Prop_13_Final_Report.pdf)

COMMON CHARACTERISTICS OF SUCCESSFUL GROUNDWATER MANAGEMENT

Elinor Ostrom, who recently won the Nobel Prize in Economics for her work on local governments' management of natural resources, identified a number of characteristics shared by successful efforts to manage groundwater resources. These characteristics include: (i) clearly defined boundaries, both in area and in participants; (ii) rules that are tailored to the local circumstances; (iii) local governance; (iv) active monitoring for compliance with adopted rules; (v) graduated sanctions for violations of those rules; (vi) conflict resolution mechanism within the institution; and (vii) support for local institutions by external governments.*

* Ostrom, Elinor (1990). *Governing the Commons: The Evolution of Institutions for Collective Action.* Cambridge University Press. ISBN 0-521-40599-8.

Case Studies in Effective Local Groundwater Mar

Glenn County Groundwater Management Plan
Structure: Groundwater Ordinance

Utilizing a mission and goals statement and a memorandum of understanding (MOU) among local stakeholders, the Glenn County Board of Supervisors adopted a groundwater ordinance in 2000. The ordinance builds on earlier work by a water advisory committee and identifies basin management objectives in key areas to help overcome challenges associated with defining safe yield and overdraft in the Sacramento Valley. Instead of a "one-size-fits-all" approach, the ordinance calls for management objectives to be set for minimum groundwater levels, minimum water quality and maximum subsidence for each of 17 sub-areas in the basin. The creation of the advisory committee, adoption of the ordinance and the subsequent adoption of a Four County MOU in 2006 have led to increased coordination and improved water resources understanding at the county and regional level. An Integrated Regional Water Management Planning process is also under way. (www.glenncountywater.org/management_plan.aspx)

Sonoma Valley Groundwater Management Program
Structure: AB 3030 / SB 1938 Plan

With a primary goal of sustaining groundwater resources for future generations, the Sonoma Valley Groundwater Management Program centers on an SB 1938-compliant plan adopted in 2007. The program includes four main management strategies: conservation, recycled water use to offset groundwater pumping, use of stormwater to recharge groundwater, and banking of winter Russian River water to recharge the basin. Cooperative efforts have helped to bring stakeholders together, while information gathered from the expansion of a voluntary groundwater-level monitoring program has led to increased understanding of the basin hydrogeology, improved public awareness, and better planning. Initiation of a groundwater banking feasibility study, a flood control / groundwater recharge study, and development of a guidebook for homeowners to better manage stormwater are expected to yield broader benefits such as reducing localized groundwater depressions and minimizing or eliminating seawater intrusion. (www.scwa.ca.gov)

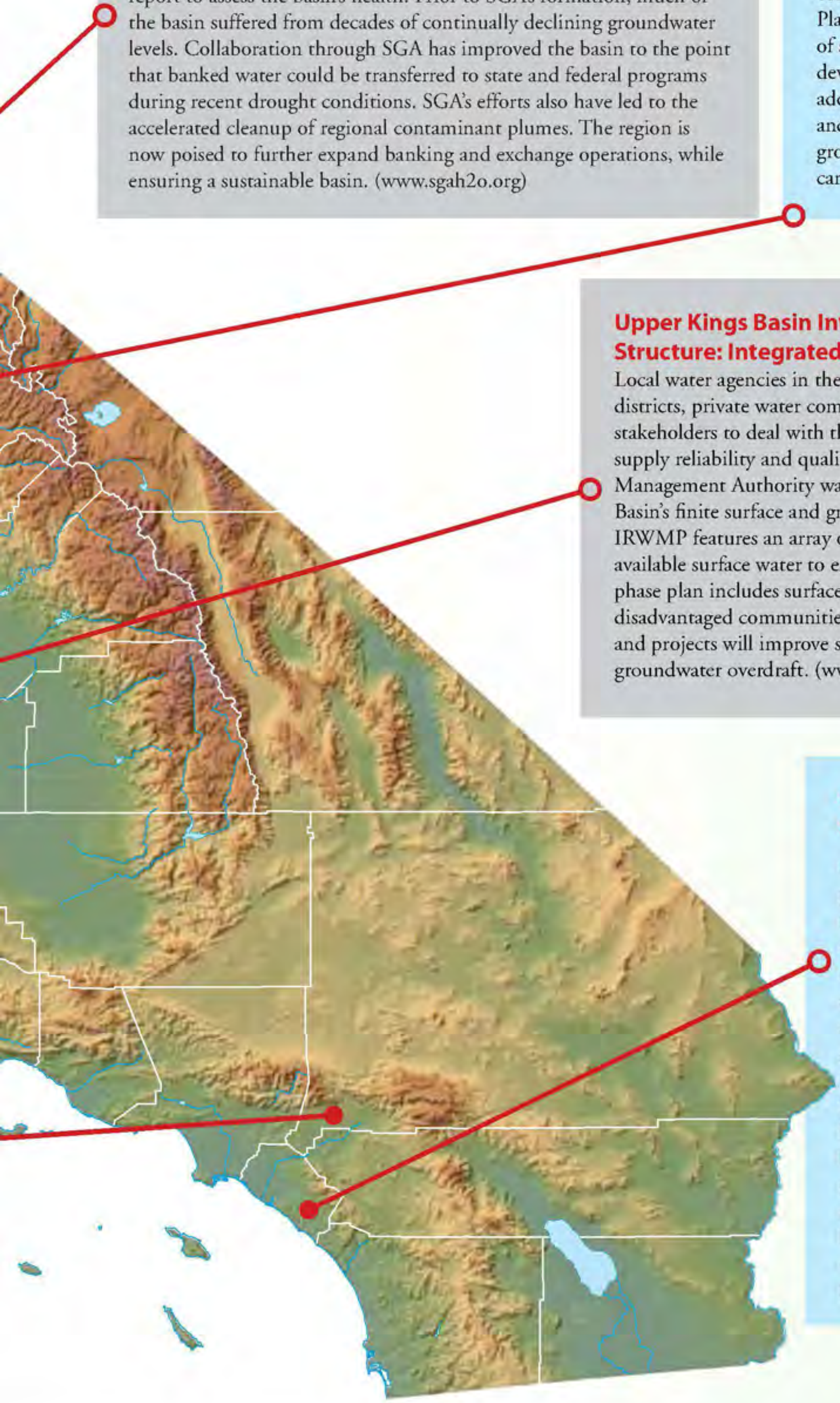
Soquel-Aptos Area Groundwater Management Plan
Structure: AB 3030 / SB 1938 Plan

Soquel Creek Water District, Central Water District, the City of Santa Cruz Water Department and the County of Santa Cruz are working cooperatively to manage resources and prevent seawater intrusion. The program centers on activities to limit water demand, maintain groundwater extractions within sustainable quantities, and closely monitor changes in all or part of four groundwater basins. Efforts include aggressive conservation, conjunctive use, and development of a seawater desalination project that will provide water for in-lieu recharge. Cooperative groundwater management has slowed the decline of coastal water levels by collectively reducing demand and reducing pumping toward sustainable levels. Opportunities for interagency projects are identified through regular communications and a collaborative approach. Projects that could not have been undertaken by any one agency are being jointly funded through cost-sharing agreements and / or Integrated Regional Water Management grant funding. (www.soquelcreekwater.org/content/groundwater-management-plan)

Chino Basin Watermaster
Structure: Adjudicated Basin

The Chino Basin Watermaster manages the Chino groundwater basin under a 1978 court judgment. Through its Optimum Basin Management Program (OBMP), the watermaster monitors production, recharge, groundwater levels, water quality and subsidence. The watermaster also carries out stormwater and supplemental water recharge activities that have increased recharge capacity by 140,000 acre-feet per year to date. Other initiatives include local and regional conjunctive use programs totaling 500,000 acre-feet, salt and nutrient management, operation of groundwater desalting facilities that produce 29,000 acre-feet of drinking water per year (soon to be expanded to 37,000 acre-feet), and 60,000 acre-feet of recycled water reuse. The OBMP has enhanced the sustainable yield of the basin, improved water supply reliability as well as water quality, reduced subsidence, and expanded the direct use and recharge of recycled water. It has also reduced demand for imported water from the State Water Project and the Colorado River. (www.cbwm.org)

agement in California



Sacramento Groundwater Authority
Structure: Joint Powers Authority

SGA draws its authority from a 1998 agreement between the cities of Sacramento, Citrus Heights, Folsom, and the County of Sacramento to utilize their common police powers to protect the basin. Through its SB1938-compliant groundwater management plan and a comprehensive update completed in 2008, SGA has developed a dedicated monitoring well network, a regional groundwater model, a comprehensive groundwater database, and a biennial basin management report to assess the basin's health. Prior to SGA's formation, much of the basin suffered from decades of continually declining groundwater levels. Collaboration through SGA has improved the basin to the point that banked water could be transferred to state and federal programs during recent drought conditions. SGA's efforts also have led to the accelerated cleanup of regional contaminant plumes. The region is now poised to further expand banking and exchange operations, while ensuring a sustainable basin. (www.sgah2o.org)

Zone 7 Water Agency
Structure: AB 3030 Plan

Zone 7 Water Agency has actively managed the Livermore Valley Groundwater Basin for more than 40 years for municipal water supply. It began importing State Water Project water into the watershed in 1962 to reduce groundwater extractions that had left the basin in overdraft. Soon after, the district began artificially recharging the basin by using local "losing" streams to convey and percolate imported water. It continues to manage the basin conjunctively through a comprehensive Groundwater Management Plan that incorporates salinity management to offset the addition of salts from imported and recycled water. Plans are being developed to augment the district's artificial recharge capacity by adding nine aggregate quarry pits that will be used as water storage and aquifer recharge basins. Through its efforts, Zone 7 has curbed groundwater pumping and replenished basin aquifers to levels that can be managed sustainably. (www.zone7water.com)

Upper Kings Basin Integrated Regional Water Management Authority
Structure: Integrated Regional Water Management Plan

Local water agencies in the Kings Groundwater Basin have created a coalition of water districts, private water companies, cities, counties, environmental interests, and other stakeholders to deal with the most pressing local water issues—groundwater depletion, supply reliability and quality. The Upper Kings Basin Integrated Regional Water Management Authority was formed in 2009 to create a sustainable supply of the Kings Basin's finite surface and groundwater resources through balanced regional planning. The IRWMP features an array of projects, including groundwater banking facilities to capture available surface water to enhance local groundwater levels and water quality. A second-phase plan includes surface water exchanges and a groundwater treatment plant to serve disadvantaged communities currently using water of lesser quality. Regional planning and projects will improve supply reliability in dry years and mitigate the Kings Basin's groundwater overdraft. (www.krcd.org/water/ukbirwma)

Orange County Water District
Structure: Special District Act

OCWD was the first agency in California to adopt a groundwater management plan. Originally adopted in 1989, the plan was updated most recently in 2009. In addition to operating one of the most advanced groundwater recharge and monitoring systems in the nation, OCWD manages the largest constructed wetlands in Southern California to naturally filter and clean Santa Ana River flows before entering the recharge area. The district has an active groundwater conjunctive use storage agreement with Metropolitan Water District of Southern California and has constructed the largest planned indirect potable reuse project in the world, the Groundwater Replenishment System, which provides 72,000 acre-feet per year of highly purified water for an expanded seawater barrier and recharge to the aquifer. Successful management of the basin has helped reduce the region's reliance on imported water from Northern California and the Colorado River. (www.ocwd.com) work collaboratively within a region to develop common water resources management goals and objectives through a transparent process including public involvement. These standards include a list of water management strategies and objectives, including surface and groundwater management, water quality protection and improvement, recycled water and desalination (where appropriate).

The intent of the IRWMP program is to encourage integrated regional strategies for management of water resources and to provide funding, through competitive grants, for projects that protect communities from drought and other extreme weather events, ensure sustainable water uses and environmental stewardship, protect and improve water quality, and improve local water security by reducing dependence on imported water.

Similar to the AB 3030 and SB 1938 processes, local and regional stakeholders have collaborated to develop common water resources management goals and objectives. Multiple plans have emerged since 2002, bolstered by over $1 billion in funding from Propositions 50, 84 and 1E for those agencies with groundwater management plans and / or an urban water management plan. It is anticipated the comprehensive approach outlined through the IRWMP process will continue to play a vital role in sustaining California's overall water supply, particularly if the considerable financial support for the program is maintained in the future.

Coordinated Agreements and Ordinances

Some agencies have entered into coordinated agreements over the years in which multiple water purveyors commit to participate in mutually beneficial management activities, including the analysis of a jointly used basin and the development of joint capital projects and joint operational policies. Enforcement of the agreement and the collection of any fees or levies may be jointly shared among the parties.

In addition, groundwater ordinances have been adopted by some cities and counties. These ordinances may include controls intended to limit or prohibit exports of groundwater to protect the area's groundwater basins. The more general intent is to better coordinate management of water supply and land development. Local governments implementing this type of groundwater management utilize their police power, land use authority and general plan provisions to regulate the use of groundwater in their jurisdiction. These governmental entities are often faced with unique, internal management issues, such as planning department goals that must be coordinated with water or public works department goals and objectives. These ordinances have been most successful when coordinated with an AB 3030 / SB 1938 groundwater management plan.

Other voluntary management strategies are less common, but they can also be successful when implemented proactively and in cooperation with other local and regional stakeholders. Coordinated agreements such as the Sacramento Area Water Forum (including the Sacramento Groundwater Authority) have produced positive results in some regions.

Adjudication

Adjudication is a management method for groundwater basins that have typically exhibited a condition of sustained overdraft for a period of at least five consecutive years. Adjudication is the product of a judicial process involving parties in a groundwater basin to determine the nature and quantity of each producer's share of the basin's safe yield. The process includes the appointment of a watermaster to oversee the court judgment that specifies how much each of the parties to the decision can extract from the basin. There are 22 settled court adjudications of groundwater basins in California, mostly in Southern California.[11] The first basin-wide adjudication of groundwater rights in California was in the Raymond Basin in Los Angeles County in 1949 (*Pasadena v. Alhambra*)[12]and the majority of adjudications were initiated or completed prior to the passage of AB 3030 in 1992.

Adjudicated groundwater basins in California can help to provide certainty by defining and quantifying specific rights for individual producers in the basin. However, application of this strategy indicates significant challenges exist in the affected basin, and parties entering into adjudication should understand the process is time consuming, expensive and complex for the involved parties.

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[11] California Department of Water Resources. Groundwater Information Center – Court Adjudications. 2011. (http://www.water.ca.gov/groundwater/gwmanagement/court adjudications.cfm)

[12] California Department of Water Resources. *California's Groundwater, Bulletin 118 - Update 2003: Ch. 2.* (http://www.water.ca.gov/pubs/groundwater/bulletin 118/california%27s groundwater bulletin 118 - update 2003 /bulletin118-chapter2.pdf)

Advancing Sustainable Groundwater Management

It is increasingly clear that California's reliance on groundwater is growing. Local groundwater management plans must reflect that reality and incorporate strategies that consider the potential consequences of a large-scale shift to groundwater, whether cyclical or permanent.

The components of AB 3030 and SB 1938, along with the Integrated Regional Water Management Plan approach, provide an excellent foundation for this type of management and their use should be encouraged and incentivized. Engaging stakeholders in the process is a key way to promote broad participation in the development of such plans. As experience shows, cooperation and participation by a wide spectrum of stakeholders — including surface water users — can be extremely beneficial to the development and implementation of sustainable groundwater management programs.

The ideal groundwater management plan addresses the resource on a local level, provides for operational flexibility, and satisfies the needs of both the environment and the economy while ensuring the continued health of the basin.

The following management objectives reflect best practices that will maximize the effectiveness and sustainability of local groundwater management plans.

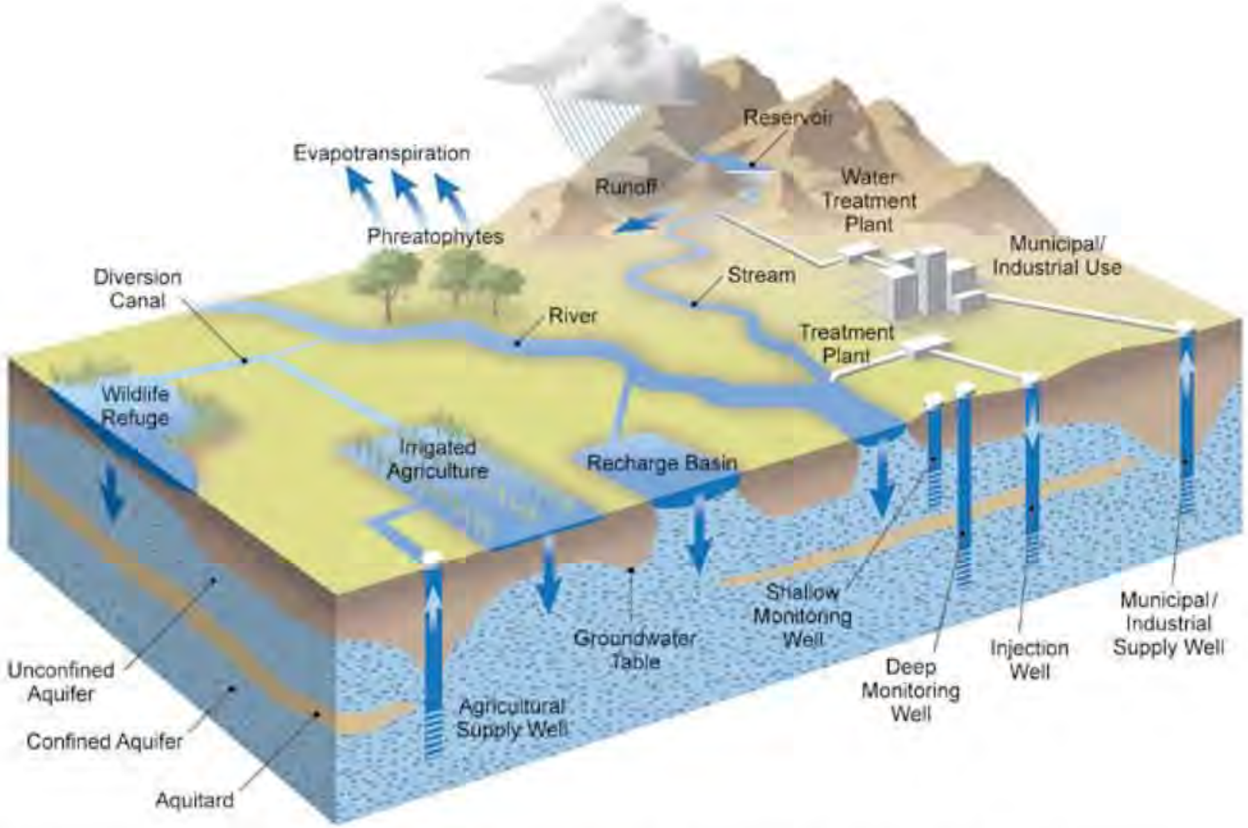
Optimize conjunctive management of surface and groundwater resources. California must invest in surface storage and conveyance improvements as part of a comprehensive plan to restore the Delta ecosystem, ensure a reliable statewide water supply and help recover, improve and sustain the state's economy. Because surface water and groundwater resources are most effective when used in concert with each other, significant investments in surface water storage and conveyance facilities are critical to the success of conjunctive use projects and sustainable groundwater management throughout California.

One of the most effective methods to do this is to ensure that grant programs and regulatory policies reflect the critical link between local and regional groundwater management programs and investments in new storage and conveyance infrastructure. This link is integral to maximizing California's overall water management flexibility.

Groundwater management agencies must also prepare for the effects of future surface water shortages and develop strategies to augment natural and artificial recharge. These strategies should include the increased use of alternative water sources such as stormwater, recycled and desalinated water, as well as additional conservation / water use efficiency efforts, to expand the portfolio of options for groundwater recharge.

Integrate conservation and water use efficiency. Many of the challenges facing groundwater management agencies are driven by the general availability of water for beneficial uses. A continued and intensified commitment to conservation and water use efficiency is critical to addressing these issues. In the context of California water management, water use efficiency means "using water more efficiently to reduce water demand for a given set of beneficial uses."

As with groundwater management efforts, water conservation and water use efficiency programs will only be successful if local water agencies are responsible for their design and implementation. Local water agencies are accountable to their customers for making locally cost-effective decisions that will provide reliable water supplies while balancing other factors, consistent with applicable regulatory requirements. Water conservation and water use efficiency programs are indispensable tools in any agency's portfolio as it develops a sustainable water management plan.



Conceptual model of a typical water management system. Courtesy of the Department of Water Resources.

Undertake comprehensive data collection and analysis. While large amounts of groundwater information are currently being collected and used by multiple local, regional, state and federal agencies and organizations, there are data gaps that can prevent the optimal beneficial use of a groundwater basin. These gaps may also affect relationships among agencies and limit opportunities for regional efforts to sustainably manage a basin's resources. Filling data gaps, ensuring adequate and sustained local groundwater monitoring and making periodic evaluations of the data are the most effective ways to gauge the long-term management risks to groundwater basins (both from a quality and quantity perspective) resulting from increased reliance on groundwater resources. Such fundamental data gathering and assessment are prerequisites to successful, sustainable groundwater management.

Sustainable groundwater management has the best chance of being achieved and maintained if a proper and frequent assessment of the state's groundwater resources is completed, including groundwater level trends, average quantities of groundwater available, and unused storage capacity. Efforts should also focus on groundwater quality data, the effects of current and future contamination and management options for better protecting basins over the long term. This assessment of the groundwater basins' level trends, availability, capacity and quality should be completed and reported by DWR and the appropriate federal agencies (e.g. USGS, NASA), working cooperatively with local groundwater management agencies and optimizing local agency data, evaluations and reports. ACWA was encouraged by the inclusion of a provision requiring such a document in the SBX7 6 legislation and has been working with DWR to develop appropriate, effective and efficient protocols for engaging with local groundwater management agencies.

Most of the groundwater served in California is well managed by local agencies utilizing the appropriate scale of monitoring, data evaluation and reporting through a well-designed groundwater management program. Those areas without, but in need of, active groundwater management programs should be identified, and local agencies should be engaged to implement strategies to move toward sustainability. However, at this time there is limited large-scale groundwater data and information available to systematically assess and accurately describe the status of groundwater basins throughout the state. In addition to developing such information, it is important that representative groundwater level and quality information already collected be made transparent and accessible to interested stakeholders, including adjacent local groundwater managers.

Local and regional entities should share appropriate information and collaborate with other pertinent agencies and the state in developing and implementing sustainable groundwater management programs. Additional efforts may be required to engage individual landowners on a case-by-case basis because sustainable local management of groundwater resources requires accountability, stewardship and transparency by all users. This data collection and transparency of information will not only provide a means for communication and education about the resource, but ultimately will help provide protection to all groundwater users, ensuring a high quality, reliable water supply in each basin. Appropriate local monitoring, measurement and reporting of groundwater basin activity are the only ways to assess whether groundwater basin objectives are being achieved.

Consider the implications of land use decisions. Land use policies that maximize conjunctive use projects and minimize subsidence and groundwater contamination often conflict with common practices of agricultural and urban development throughout California. The constant pressure of residential and commercial development can result in the loss of critical acreage that could be utilized to recharge groundwater basins or ensure storage for areas with unreliable surface supplies. Ironically, areas developed in a way that prevents adequate recharge have the potential to suffer subsidence and a loss of the infrastructure built over the basin. IRWMPs can be an important tool in minimizing such impacts, but it is necessary to collaborate with the developer community to ensure effective communication and reduce potential conflict.

Local agencies should be proactive in identifying and including in a sustainable groundwater management plan the most appropriate areas to serve as dedicated recharge or conjunctive use locations. In addition, land use practices to protect indirect recharge should be promoted to land use jurisdictions for their consideration and implementation, through ordinance where necessary. One example of an indirect approach to conjunctive use is promoting low-impact development (LID), a strategy increasingly used to improve the effectiveness of groundwater recharge and extraction options by minimizing the loss of recharge areas and requiring certain construction practices that increase or maintain the absorption capability of lands overlying groundwater basins. Such efforts, when developed and implemented in coordination with other actions such as enhanced water use efficiency and / or water recycling, present an important opportunity for coordination with local governments and collaboration with stakeholders.

Make public communication and education a priority. Many local and regional groundwater management agencies continue to improve and implement plans that effectively maintain or enhance the health of their basins and provide the foundation for future sustainable management activities. Efforts to educate the public (including policy makers, other local agencies and regulators) about groundwater and successful management approaches can be significantly improved and should be a higher priority for agencies already implementing or working to craft a sustainable groundwater management plan. Information should be made available in a variety of formats and regular workshops should be designed to appeal to all audiences.

WHAT IS LOW-IMPACT DEVELOPMENT?

Low-impact development (LID) is a sustainable practice that benefits water supply and contributes to water quality protection. Unlike traditional stormwater management, which collects and conveys stormwater runoff through storm drains, pipes, or other conveyances to a centralized stormwater facility, LID takes a different approach by using site design and stormwater management to maintain the site's pre-development runoff rates and volumes. The goal of LID is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source of rainfall.*

* State Water Resources Control Board. *Low Impact Development – Sustainable Storm Water Management*. 2011. (http://www.swrcb.ca.gov/water_issues/programs/low_impact_development/index.shtml)

THE 2009 LEGISLATIVE WATER PACKAGE

The comprehensive water package enacted in November 2009 marked a new era for California water. At its core, the new law formalized the co-equal goals of water supply reliability and ecosystem health as state water management policy. The package includes four policy bills and an $11.14 billion water bond measure now targeted to go before California voters on the November 2012 ballot. The policy bills address the Delta ecosystem and its governance, statewide conservation policies applicable to urban, industrial and agricultural water suppliers, development of updated in-stream flow criteria, and groundwater elevation monitoring requirements in every basin and sub-basin in California.

While all of the bills include policies or actions that will directly or indirectly impact groundwater resources, the groundwater monitoring bill, SBX7 6, requires the most of groundwater managers and users. This legislation requires groundwater elevation monitoring for all basins and sub-basins by January 1, 2012 to demonstrate seasonal and long-term elevation trends in groundwater basins. The monitoring provisions are designed to help better manage the resource during both normal water years and drought conditions.

Under the legislation, a local agency or other eligible organization in each basin or sub-basin interested in assuming responsibility for monitoring and reporting groundwater elevations for its respective area was to notify DWR by January 1, 2011. If no entity volunteers for a particular area, DWR will assume the responsibility for monitoring and the affected county and entities will become ineligible for state grants or loans.

This legislation supports local groundwater management by appropriately looking to local and regional agencies as the authorities for monitoring groundwater elevations. ACWA has been an active partner with DWR as the monitoring program protocols have been developed. The state's commitment to supporting the local management approach will help ensure effective implementation.

In addition to the groundwater provisions in SBX7 6, accomplishing the goals included in the Delta package will be a critical part of securing a healthy Delta ecosystem and improvements in water supply reliability for the entire state. It will allow for a more reliable surface supply for users who may otherwise shift to groundwater to satisfy part or all of their water needs.

Implementing activities to reach conservation targets outlined in SBX7 7 will also be important as local agencies seek to reduce long-term stress on groundwater resources, particularly during periods when access to surface water supplies is reduced or eliminated.

While this historic package of water legislation includes much that will contribute to improved water management in California, it alone will not lead to sustainable groundwater management. Though it reflects recognition that the state is facing a multi-faceted water crisis and provides policy and financial support for many projects, much work remains to be done to ensure groundwater resources can be sustained through active management on a local or regional scale.

Recommendations

Throughout this Framework ACWA has described key elements of groundwater management and the growing number of challenges facing local water managers today. Examples of successful, locally coordinated approaches to groundwater management have been provided to highlight best practices that may enhance the effectiveness of management plans. Plans such as these should be developed and expanded at the local or regional level, understanding that sometimes there is a need to engage beyond an individual agency's jurisdictional boundaries.

ACWA firmly believes the state Legislature should encourage and support local management policies that appropriately reflect California's geographic and hydrologic diversity rather than institute a state-administered centralized control structure for regulating or permitting the use of groundwater. Statewide permitting and regulation would undermine the effectiveness of existing and planned local investments and would be counterproductive. The Legislature should focus instead on incentivizing the development and implementation of the best practices outlined in this Framework.

In addition, ACWA stands ready to collaborate in the development of appropriate regulatory and policy-related actions and initiatives that will further promote more effective and comprehensive local groundwater management. To that end, we make the following management and policy recommendations to help ensure the sustainability of California's groundwater resources.

ACWA Groundwater Framework Recommendations

Local Agency Level

1. Excluding small or undeveloped basins, groundwater basins in California that are identified in DWR Bulletin 118 should be operated by local agencies and / or stakeholders consistent with a locally developed groundwater management plan that achieves sustainability with the level of management appropriate for the basin. Groundwater management agencies within any basin where extractions are a significant percentage of the groundwater budget should develop formal groundwater management plans with stated policies and practices. The development of these plans should be open and transparent to allow public engagement in the process and should specifically address all factors related to groundwater management including, but not limited to, conjunctive use where appropriate.

2. Consistent with their respective groundwater management plans and state law, groundwater management agencies should be encouraged to collect and disseminate comprehensive groundwater information to demonstrate short- and long-term sustainability of the basin. Agencies should actively provide that information to DWR and make it accessible to the public.

3. Agencies that do not have an SB 1938 groundwater management plan (or functional equivalent), where applicable, should be ineligible for water-related state grants and loans. Financial support and incentives should be made available to agencies that lack sufficient resources but are committed to developing a groundwater management plan.

State and Regional Agencies

1. DWR should improve the functionality of existing online access portals such as IWRIS and the Water Data Library for groundwater information that utilizes the data collected from local agencies to provide improved public access. Representative information should also be transparent and accessible statewide through other avenues, including the California Water Plan (Bulletin 160) and any updates to Bulletin 118.
2. Where an SB 1938 groundwater management plan (or the functional equivalent) exists, state agencies should develop procedures, where applicable, to issue necessary permits for groundwater projects within 60 days of the certification of the CEQA document by the lead agency. This is especially critical for groundwater replenishment projects.
3. A multi-agency team led by DWR should be created and charged with developing an approach to both coordinate review and facilitate implementation of new local and regional groundwater recharge, groundwater banking and conjunctive use projects. Interagency coordinated review and facilitation of groundwater projects is required to ensure that these sustainable resource management opportunities are implemented efficiently once approved by a local agency as part of its groundwater management plan.
4. The Natural Resources Agency and Cal/EPA should work together to develop incentives for local agencies to implement small-scale groundwater replenishment projects, consistent with the applicable local groundwater management plan.
5. Regional Water Quality Control Boards should encourage and facilitate the process for capable local agencies responsible for groundwater management to proactively remediate contaminated groundwater basins when the local agency determines such remediation will contribute to more sustainable groundwater management.
6. The California Department of Public Health should develop draft criteria for SB 918 (2010), which directs the California Department of Public Health to develop criteria for using recycled water to supplement water storage, no later than December 31, 2011.
7. California agencies must develop a new methodology for encouraging, promoting and supporting infrastructure investments, particularly those that would improve water supply reliability at the local level and those that can work in conjunction with the state's backbone water delivery systems.

Legislative / Legal

1. The state of California should designate the use of surface water for groundwater recharge as a "beneficial use." The designation should apply even when there is no plan for future extraction of the water, as long as it is consistent with an SB 1938 groundwater management plan (or the functional equivalent).
2. California law should be clarified to state that once surface water is recharged as part of a conjunctive use project consistent with an SB 1938 groundwater management plan (or the functional equivalent), such water becomes "groundwater" outside the scope of State Water Resources Control Board jurisdiction.
3. The state of California should provide appropriate protection from liability for any agency responsible for groundwater management that undertakes the cleanup of a contaminated groundwater basin in order to use that basin, including as part of a conjunctive use program.
4. Voting requirements should be reduced to 55 percent for approval of local funding initiatives targeted at investments in new or existing water management infrastructure.
5. California anti-degradation policy, as it is currently interpreted with respect to groundwater recharge projects, should allow local agencies to optimize their groundwater resources, providing that maximum benefit to the public is maintained. Any changes should be made in coordination with groundwater management plans, recognizing the variety of different circumstances throughout the state.
6. County general plans should be required to incorporate land use elements that contribute to and promote effective implementation of an SB 1938 groundwater management plan (or the functional equivalent), as determined in consultation with local agencies responsible for groundwater management.

7. The state of California should ensure that "in-lieu" recharge is protected as part of a conjunctive use program. Put otherwise, a conjunctive use project need not require the direct recharge of surface water or the actual extraction of groundwater if near-term demands can be shifted from one source to the other, thereby accomplishing the goal of the conjunctive use project in both wet and dry years.

Collaborative Actions

1. In order to implement large-scale conjunctive use projects in the Central Valley and elsewhere, the Legislature and federal government should invest in surface water storage and improved Delta conveyance, provide financial support for local and regional infrastructure projects, and modify operations and regulatory policies to optimize conjunctive use opportunities.
2. The state, working with appropriate local entities, should address groundwater-related drinking water quality issues in small or disadvantaged communities by providing technical assistance to identify the best approach to protecting public health.
3. In implementing applicable state laws and developing ordinances, local governments should carefully consider the implications of policies and regulations that affect land use in the areas that overlie basins and advocate projects in collaboration with the developer community that maximize opportunities for recharge and conjunctive use.
4. Sustainable groundwater management may be improved through the use of quantitative groundwater models; state and federal agencies should provide financial support to assist local agencies in constructing such models where appropriate.
5. Protecting groundwater quality should be considered as important as the development of sustainable groundwater supplies. Using the best available science, regulatory and policy efforts to identify long-term solutions for the remediation of contamination issues should be supported on a local, regional and statewide scale, such as the salt and nutrient management plans identified in the State Water Resources Control Board Recycled Water Policy.

BDCP1738.

ACWA Policy Principles on Groundwater Management

"Groundwater – Invisible No More"

Groundwater is an invaluable resource for California and a critical asset in the state's comprehensive water management portfolio. Groundwater management should be implemented throughout California, and should be done so consistent with the following policy principles adopted by ACWA's Board of Directors.

1. Groundwater resources are best managed by local jurisdictions to effectively and efficiently manage water quality and supplies for beneficial uses. ACWA encourages and supports regional groundwater management strategies such as Integrated Regional Water Management Plans (IRWMP) and other regional partnerships.
2. Local management of groundwater resources requires accountability, stewardship and transparency; and appropriate local monitoring, measurement and reporting of groundwater basin activity to assure groundwater basin objectives are being achieved.
3. ACWA opposes state interference with existing legal rights to groundwater and believes that a state-administered water rights system for groundwater would undermine effective groundwater management and local investments.
4. California's groundwater resources are unique and diverse in physical characteristics, beneficial uses, water rights, legal and institutional governance and management structures, stakeholders and other features. One-size-fits-all state mandates are ineffective and counterproductive.
5. ACWA supports expansion of conjunctive management of surface water and groundwater supplies that contributes to the protection, reliability and sustainability of local, regional and statewide water supplies for water users and the environment. Such an expansion requires increased groundwater and surface storage, the re-operation of surface reservoirs as appropriate, and improved Delta conveyance.
6. Groundwater quality management is integral to optimizing California's groundwater resources. It must be science-based and include improved data management, basin assessments, monitoring, reporting, protection and, where appropriate, remediation.
7. ACWA supports the use of potable, desalinated, recycled and storm waters for groundwater recharge, with appropriate water quality safeguards that protect beneficial uses.
8. Land use policies and regulations that identify, preserve and protect natural and artificial recharge and extraction capabilities are essential for sustainable groundwater management. Land use policies must consider and analyze impacts and potential impacts to groundwater quality.
9. ACWA supports statewide and regional regulatory consistency that acknowledges the diversity of groundwater resources to facilitate the achievement of local and statewide groundwater storage and basin utilization goals.
10. Groundwater management strategies must anticipate and adapt to the effects of climate change.
11. Optimal groundwater management throughout California will require significant federal, state, regional, local and private investment in infrastructure and related facilities. ACWA further supports increased funding for groundwater research, monitoring, and other management programs.
12. ACWA encourages other statewide associations, regional entities and groundwater-related organizations to educate and advocate for expanded and more effective groundwater management throughout California, and will help coordinate such activities.

ACWA Groundwater Committee

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ACWA is a statewide non-profit association whose 450 public agency members are responsible for about 90% of the water deliveries in California.

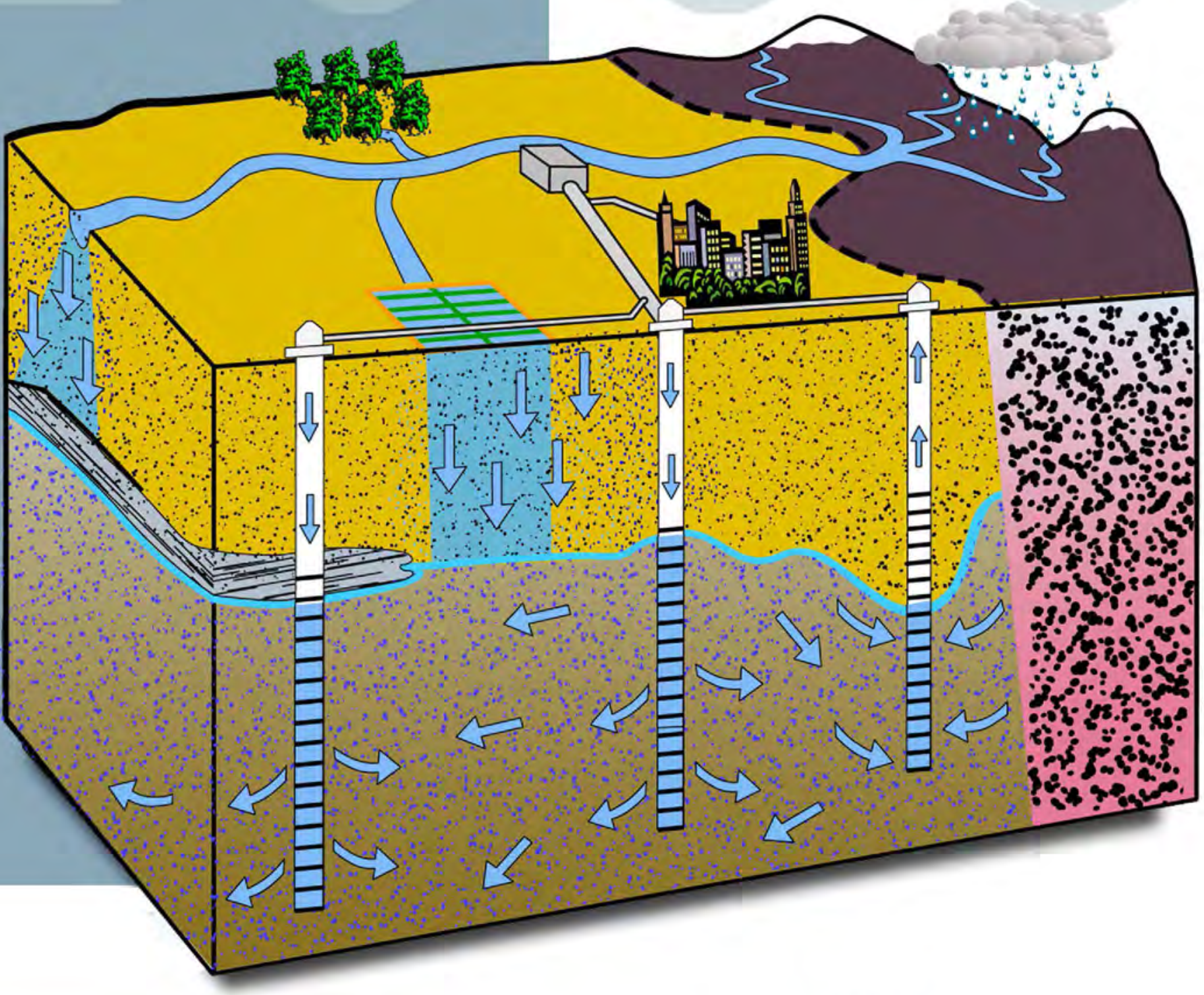
MISSION.

ACWA's mission is to assist its members in promoting the development, management and reasonable beneficial use of good quality water at the lowest practical cost in an environmentally balanced manner.

GROUNDWATER AND SURFACE WATER IN SOUTHERN CALIFORNIA

A GUIDE TO CONJUNCTIVE USE

Published by the Association of Ground Water Agencies



PREPARED FOR: AGWA
Association of Ground Water Agencies

BY: MONTGOMERY WATSON
Water Education Foundation

Association of Ground Water Agencies

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Background

The Association of Ground Water Agencies, or AGWA, was formed in 1994 by a group of eight groundwater basin management agencies. In 1995, it was incorporated in Southern California as a nonprofit Public Benefit Corporation.

Mission Statement

The mission of the Association of Ground Water Agencies is to promote interagency solutions that enhance the quality and management of groundwater resources.

AGWA's purpose is to create a forum for the discussion of groundwater issues for management of our groundwater basin resources, and to take action in connection with these. AGWA's primary objectives are to:

- promote enhanced management of groundwater basins
- improve the reliability of existing groundwater supplies
- assure the protection and enhancement of groundwater quality

Members and Affiliates

Membership in AGWA consists of Members and Affiliates. Membership as of July 1999 is listed below.

Members

Calleguas Municipal Water District
Chino Basin Watermaster
Eastern Municipal Water District
Kern County Water Agency
Main San Gabriel Basin Watermaster
Mojave Water Agency
Orange County Water District
Raymond Basin Management Board
San Bernardino Valley Water Conservation District
Six Basins Watermaster
Tehachapi-Cummings County Water District
Upper Los Angeles River Area Watermaster
Water Replenishment District of Southern California
Western Municipal Water District

Affiliates

Basic Compliance Engineering
Bookman-Edmonston Engineering
Cadiz, Inc.
CH2M Hill
Komex H2O Science
Metropolitan Water District of Southern California
Montgomery Watson
Narver Associates
Psomas and Associates
City of Riverside
San Gabriel River Water Committee
Stetson Engineers, Inc.

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and the
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http://www.water-ed.org

GROUNDWATER AND SURFACE WATER IN SOUTHERN CALIFORNIA

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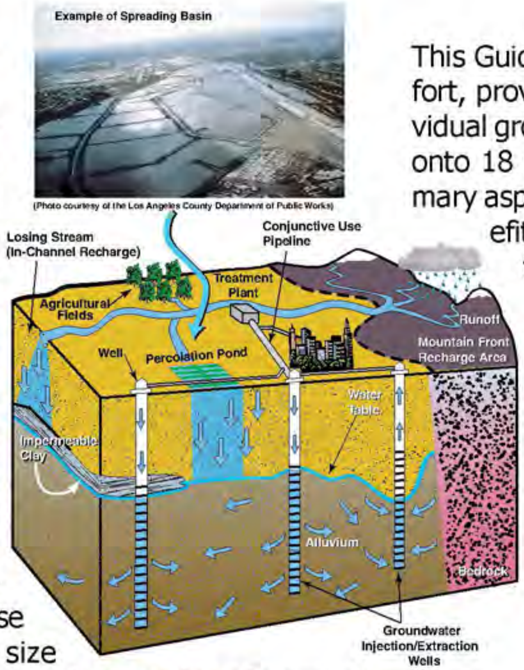
Executive Summary

Groundwater (underground water) is a critical component of California's water supply. The semi-arid climate of California has prompted the development of our groundwater resource to supplement our surface water supply. Some critical facts about groundwater include:

- The amount of underground water stored in California is far greater than that stored in the state's surface water reservoirs, although only a portion of these groundwater resources can be practically and economically extracted for use.
- Groundwater serves as our only supply in those areas of the state isolated from surface water connections.
- In an average year, groundwater meets about 30 percent of California's urban and agricultural water need. In drought years, when surface supplies are reduced, groundwater supports an even larger percentage of use.
- As the state-wide population continues its growth toward a projected 47.5 million people by 2020, the demand for water will continue to increase and further development of our groundwater resources will help meet this demand.
- Meeting this demand will require significant improvements and innovations in how we optimize our existing water supplies. One of these ways is the storage of excess water during wet years beneath the ground for use during dry years. **This coordinated management of surface water and groundwater is called conjunctive use.**

The Association of Ground Water Agencies (AGWA), representing major groundwater basin management agencies throughout Southern California, formed in 1994 to promote interagency solutions that enhance the effective management of groundwater resources, especially conjunctive use. Focusing on 18 major Southern California groundwater basin groupings, this AGWA publication represents the most comprehensive evaluation to date of the potential to significantly improve the coordinated use of surface water and groundwater to meet California's water needs. Based on a survey of groundwater basin managers, this document describes areas where conjunctive use is (or may be) a viable groundwater basin management option, and will serve as a useful educational tool for teachers, legislators, elected officials, lay people, and technicians.

Prepared for AGWA Association of Ground Water Agencies by MONTGOMERY WATSON and Water Education Foundation



By no means a new concept, conjunctive use was first used in California during the Spanish mission era. Ongoing since the 1940s and shown in the photo on the next page, the spreading of surface water in Los Angeles County provides critical recharge of the underlying groundwater basins. Conjunctive use programs vary in size and type, depending on the specifics of a groundwater basin. The following figure depicts some of these storage and retrieval methods. Through the preparation of this guide, **AGWA has documented that over 21.5 million acre-feet of additional groundwater storage is available in Southern California groundwater basins, enough to fill Diamond Valley Lake, our largest surface water reservoir, 26 times.** One acre-foot of water is approximately 326,000 gallons, enough water to cover a football field to a depth of one foot. This stored water could be used during times of drought or natural disaster when surface water supplies are not available. This storage would reduce some of the need for the construction of large dams and reservoirs, which are expensive and often viewed as environmentally unfriendly.

To evaluate this storage potential, AGWA surveyed each of the groundwater basin managers to obtain data used in this study. Montgomery Watson assisted AGWA in the analysis of data and presentation of survey results. The Water Education Foundation prepared the overview of conjunctive use. In analyzing each basin, this Guide includes information on basin location, basin management (governance), available storage, present operational safe yield, and basin sediments (geology).

This Guide represents the culmination of that effort, providing overviews for each of the 85 individual groundwater basins evaluated and grouped onto 18 maps. The Guide also explores five primary aspects of conjunctive use: 1) need, 2) benefits, 3) methods, 4) governance, and 5) potential problems.

In summary:

- Conjunctive use is a well-proven method to increase our ability to meet California's increasing water demand.
- Conjunctive use improves water supply reliability.
- The need for environmentally controversial surface water reservoirs may be reduced by conjunctive use programs.
- Assuming resolution of institutional, water quality, and other issues, over 21.5 million acre-feet of additional water can be stored and used in Southern California groundwater basins.

Summary of Long-Term Storage Potential of the Basins Included in This Guide.

Basin Groupings	Potential Storage for Use in Dry Years* (Acre-Feet)
Kern County Basin	8,000,000
Tehachapi/Cummings Basin	Not Available as of July 2000
Ventura County Basins	500,000
San Fernando Valley Basins	150,000
Raymond Basin	144,000
San Gabriel Basin	400,000
Los Angeles Coastal Plain Basins	1,089,000
Orange County Coastal Plain Basin	300,000
Six Basins	30,000
Upper Santa Ana River Basins	1,854,000
Bunker Hill Basin	0
San Jacinto Watershed Basins	1,284,000
Upper Santa Margarita River Basins	200,000
San Diego County Basins	270,700
Mojave River Basins	1,790,100
Hayfield Basin	500,000
Cadiz Valley Basin	1,000,000
Coachella Valley Basin	4,000,000
TOTAL	**21,511,800**

* Data provided by groundwater basin managers

Association of Ground Water Agencies

A Guide to Conjunctive Use in Southern California

What is Conjunctive Use?

Conjunctive use is the coordinated management of surface water and groundwater supplies to increase the yield of both. The conjunctive use concept is intended to increase total supplies and enhance water supply reliability.

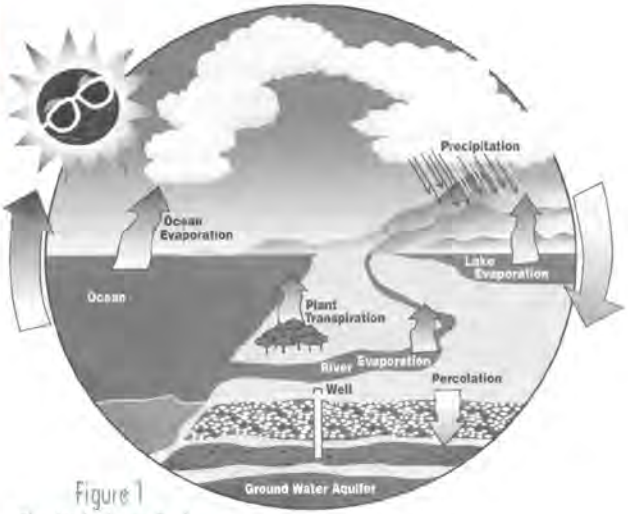


Figure 1
The Hydrologic Cycle
(courtesy of
Water Education Foundation)

Why Conjunctive Use?

Water is essential to life in California. It fuels industries, grows crops, provides habitats for thousands of plant and animal species, and allows over 33 million Californians a cool, refreshing drink.

In nature and without our intervention, water is continuously recycled. Water evaporates from oceans, lakes, streams and rivers, condenses into clouds, and returns to earth as precipitation, most commonly, in the form of rain and snow. From there, rain and melted snow flow back into lakes, rivers and oceans, replenishing these surface supplies and continuing the hydrologic cycle (Figure 1). Though much of California's water comes from these surface supplies, water from the surface also percolates into the ground creating California's largely unseen water supply: groundwater.

In California, on average, 15 million acre-feet (one acre-foot of water is approximately 326,000 gallons, enough water to cover a football field to a depth of one foot or supply one to two families for a year) of groundwater (underground water) are extracted from wells each year. With more than half of all Californians relying on groundwater for at least a portion of their water supply, groundwater supplies approximately 25-30 percent of California's water needs. The state's population is expected to reach 47.5 million by 2020 and approximately one-half (7 million people) of this growth is anticipated to occur in Southern California (Figure 2). With this growth will come an increased reliance on groundwater.

Benefits of Conjunctive Use

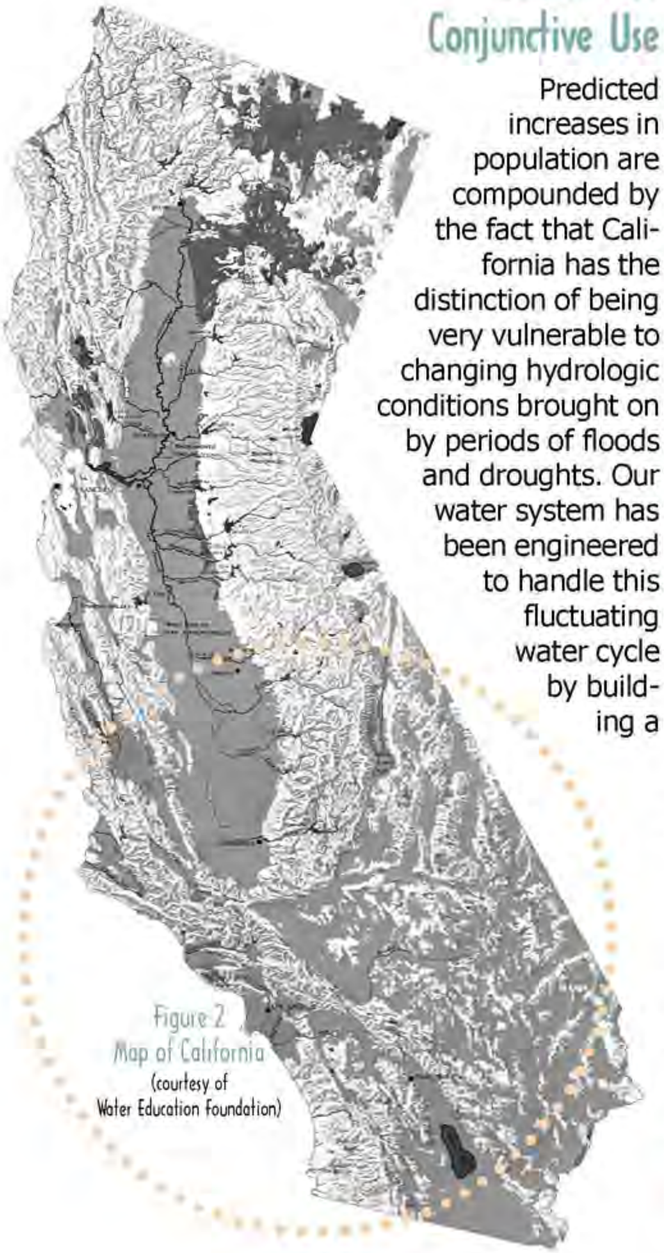


Figure 2
Map of California
(courtesy of
Water Education Foundation)

Predicted increases in population are compounded by the fact that California has the distinction of being very vulnerable to changing hydrologic conditions brought on by periods of floods and droughts. Our water system has been engineered to handle this fluctuating water cycle by building a series of large, above-ground reservoirs to hold water when it is needed. Despite the integral role that above-ground reservoirs can have in conjunctive use, they are expensive to build and are viewed by some as environmentally damaging. Thus, greater use of storage capacity in aquifers via conjunctive use has become an increasingly popular alternative for water storage, thereby improving California's water supply.

As defined previously, conjunctive use is the coordinated management of surface water and groundwater supplies to increase the yield of both. It is intended to increase total supplies and enhance water supply reliability–in essence to rely more on surface water supplies during wet or normal years and groundwater in dry years. This process can be enhanced by storing excess water supplies underground during wet years for use during the dry year–a form of drought proofing. Figures 3 and 4 illustrate the concept of conjunctive use and methods commonly used to introduce and remove groundwater from the subsurface.

Currently, during droughts, the state turns to aquifers as if they were savings accounts — relying on groundwater for as much as 60 percent of a year's supply to keep farm fields in production and urban areas supplied with water. In addition, Southern California receives a large part of its water from the Sacramento-San Joaquin Delta near San Francisco, Owens Valley east of the Sierra, and the Colorado River– all of which are subject to changing conditions from wet years to droughts.

The potential for conjunctive use projects is phenomenal given that aquifers in the state hold 850 million acre-feet of water, nearly 20 times the amount of water that can be stored behind all of California's dams. However, some of this amount may not be usable because of salt water intrusion, subsidence, poor quality, or high pumping costs. If California were flat, the volume of its groundwater would be enough to flood the entire state eight feet deep! In addition to a more assured supply of water during dry years, conjunctive use also can reduce pumping costs for water users because of the decreased lift. With more water in the aquifer, water is closer to the surface and therefore requires less energy (and money) to pump it out. Conjunctive use also can maximize water use more efficiently than groundwater and surface water projects operated separately – allowing for greater conservation.

Other advantages of conjunctive use include the ability to use and expand upon existing facilities, thus allowing for easier integration and a staged development approach; a smaller drainage system; fewer costs from canal lining; reduced evapotranspiration losses; reduced danger from dam failure; and improved timing of water distribution. Other possible advantages and possible disadvantages are listed in Table 1. Actual advantages and disadvantages will vary by project.

Methods of Conjunctive Use

Conjunctive use can be applied in several ways. One method uses artificial recharge by placing the water directly into the aquifers through percolation and/or injection. Percolation occurs naturally as part of the hydrologic cycle but can be enhanced by creating spreading basins atop aquifers. Water also can be put into an aquifer using wells and pumps to inject water.

Example of Spreading Basin

(Photo courtesy of the Los Angeles County Department of Public Works)

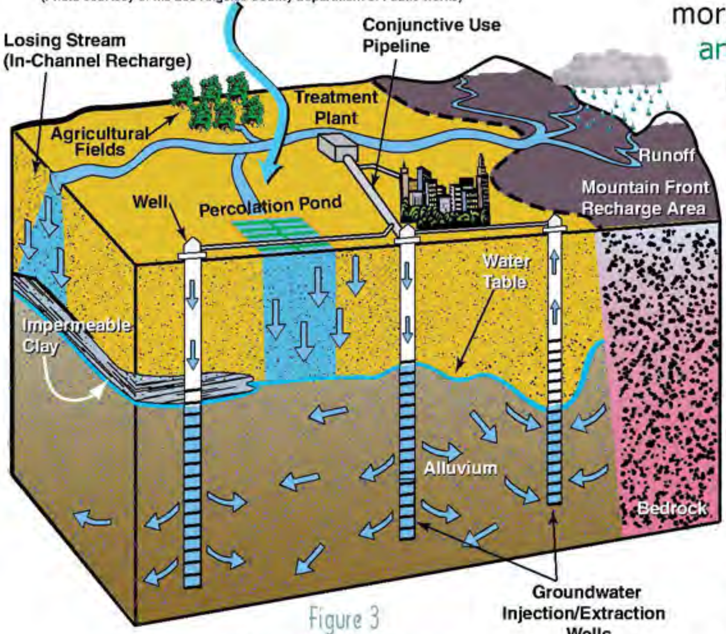


Figure 3
Conjunctive Use Program
Wet or Normal Year Operation

Another method, in-lieu recharge, works on the idea of reducing the amount of water pumped from the aquifer. That is, those who would normally rely on groundwater wells to meet their water needs instead use excess surface water supplies when available. This allows groundwater supplies to be replenished indirectly.

Rules Governing Conjunctive Use

In groundwater basins where overdraft occurs, groundwater users may work with the court to adjudicate a groundwater basin. Adjudication allows specific water rights to water users and compels the cooperation of pumpers. In other words, in adjudicated basins, the amount of groundwater that may be pumped annually by users is limited. This limit is generally based on the concept of "safe yield"—the amount of water that can be pumped each year without causing a continual reduction of water in storage (overdraft). The safe yield is dependent upon the average amount of water that can be stored in and used from the groundwater reservoir over a period of normal water supply under a given set of conditions. The safe yield of the basin, in some cases, can be substantially augmented by engineering controls. For example, more water can be made available through artificial recharge by spreading or injection wells, or by lowering groundwater levels to reduce evapotranspiration, to capture rejected recharge, or to capture surface water from streams. Safe yield augmented by such engineering controls is referred to as "operational yield" in this guide.

Of the 18 groundwater basins adjudicated in California, 17 lie in Southern California, primarily due to development pressures and an absence of adequate natural surface water supplies.

Another tool which helps manage groundwater use is AB 3030 (California Water Code Sections 10750-10756). Passed in 1992 by the State Legislature and placed into effect on January 1, 1999, this measure is intended

Table 1

POSSIBLE ADVANTAGES AND DISADVANTAGES OF USING AQUIFERS FOR STORING WATER UNDERGROUND*

Possible Advantages	Possible Disadvantages
Water quality improvement	Less hydroelectric power through avoidance of dam construction
Water supply reliability	Greater power consumption to extract groundwater
Greater water conservation	Increase in salt loading
Decreased dependence on imported supply during dry years and emergencies	More involved project operation
Less additional surface storage required	More difficult cost allocation
Fewer drainage system improvements	Over-pumping may cause land subsidence
Greater flood control	Liquefaction from shallow groundwater levels
Ready integration with existing development	May require active control of salt water intrusion
Storage programs can be phased	May cause contaminant movement
Low evaporative losses	Increased groundwater monitoring
Improvement of power load and pumping plant use factors	Increased need for diversion and/or conveyance of surface water during wet years
Less threat from dam failure	
Better timing of water distribution	

*** NOTE: Specific possible advantages and disadvantages will vary from project to project and should be evaluated on a case-by-case basis.**

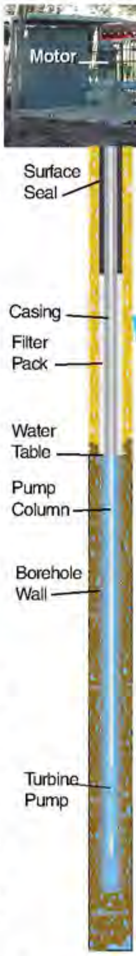
to provide local water agencies with the ability to tailor groundwater management plans to meet problems in their area (subsidence, salt water intrusion, contamination). The law does not allow local districts to impose binding water rights on pumpers but does, after a general election, allow them to impose fees on pumping. Additionally, in the 1994 case of *Baldwin v. County of Tehama*, it was determined that state law does not preclude cities and counties from regulating groundwater.

Problems Facing Conjunctive Use

Conjunctive use projects should be actively managed to avoid problems such as overdraft and pollution.

According to the California Department of Water Resources, in an average year, Californians use approximately 1.3 million acre-feet more groundwater than is either naturally or artificially

Example of Groundwater Injection/Extraction Well



recharged. This groundwater overdraft can create problems including subsidence and salt water intrusion. Additionally, increasing basin yield may necessitate large fluctuations in water levels, which can contribute to these problems.

Subsidence may occur when too much groundwater is pumped and the subsurface sediments are drained. Once drained, these sediments can compact under the weight of the overlying soil, creating depressions and fissures at the ground surface.

Salt water intrusion also can result from lowering of water levels in an aquifer. For example, drawing large volumes of groundwater out of an aquifer can cause groundwater levels to be lower than sea level. When this occurs in a coastal location, seawater has a higher elevation than groundwater, thereby enabling seawater to flow from a higher elevation to a lower elevation into the aquifers and toward the areas where the groundwater was removed. Once salt water infiltrates a groundwater basin, water quality can be seriously degraded. Since the 1950s and 1960s, water agencies have combated this problem by injecting surface water into the ground or by recharging water in spreading basins. By doing so, a hydraulic barrier is created between the freshwater aquifer and the intruding salt water.

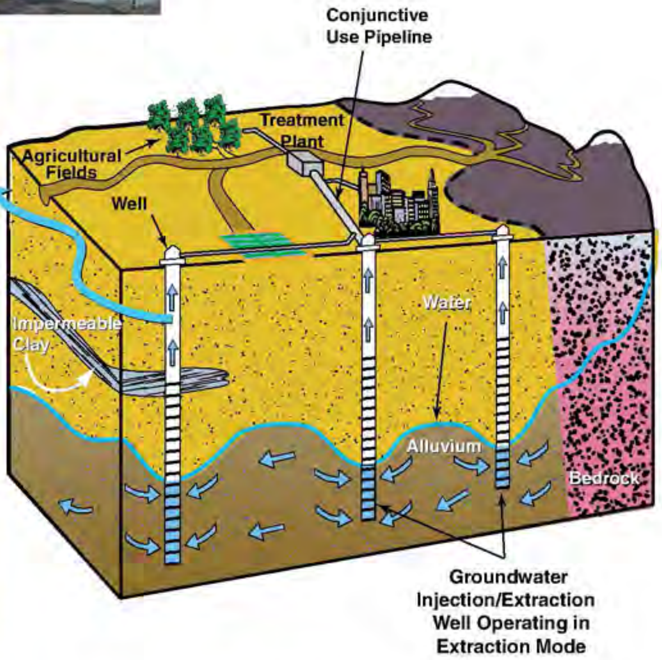


Figure 4
Conjunctive Use Program
Dry Year Operation

Pollution from both naturally occurring and manmade contaminants also can cause problems for groundwater users. Radon and arsenic, both natural byproducts of decaying rocks, occur in various areas throughout California. Contaminants from urban and agricultural centers can result from leaking gasoline tanks, sewers, landfills, industrial waste discharges, fertilizers, pesticides, and failed septic systems. In Southern California, fuels and solvents – the byproduct of military bases and private industries that support defense efforts – have been found in several groundwater basins including the San Gabriel and San Fernando Valleys. These sites are being cleaned up under the supervision of local, state and federal agencies. High concentrations of nitrates and total dissolved solids resulting from agricultural activities also pose serious threats to groundwater quality.

Increased monitoring, detection and advanced treatment techniques are helping to curb these threats to groundwater.

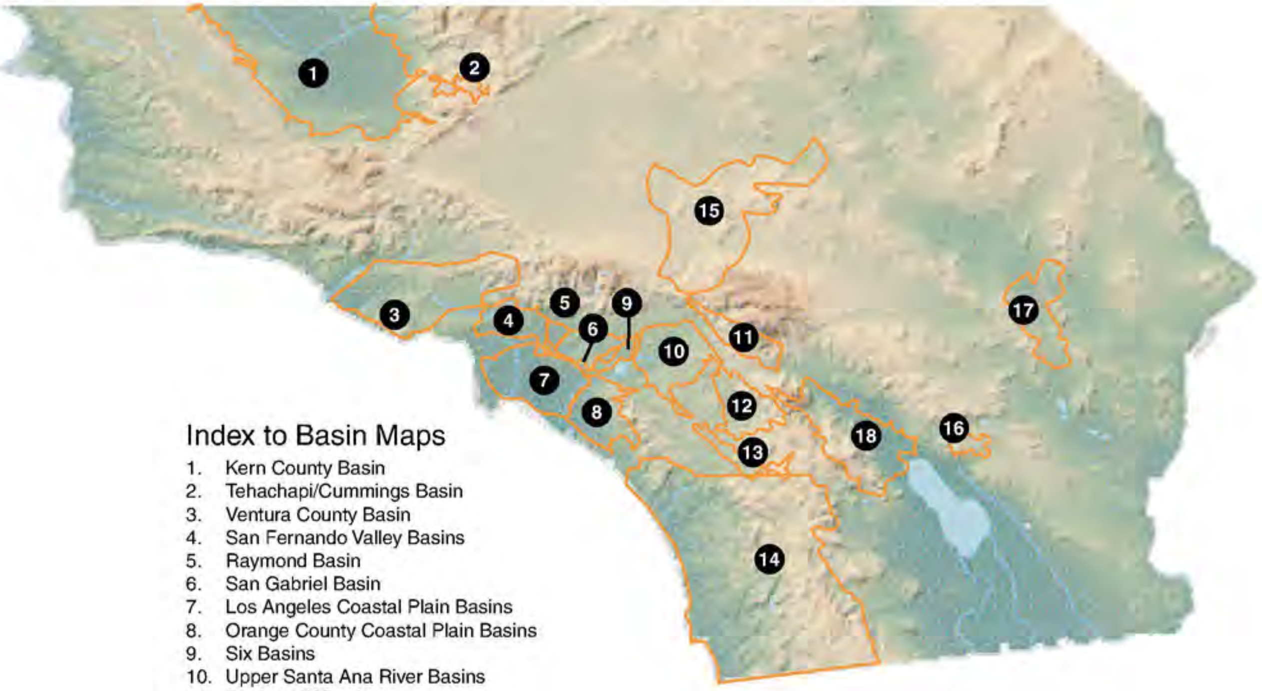
Additional problems facing conjunctive use projects may include less new hydroelectric power production due to fewer new dams; decreased well pumping efficiency; more complex project operations and consequently, more difficult cost allocations; and the reliance on artificial recharge to keep the project operating.

Conjunctive Use Potential In Southern California

In preparation of this document, AGWA surveyed and collected information from 25 management agencies for approximately 85 individual groundwater basins in Southern California. The managers were asked to provide the following information for each basin:

- Conjunctive Use
- Replenishment Activities
- Overview of Groundwater Basin
- Water Supply and Demand
- Type of Aquifers Within Basin
- Basin Size
- Basin Storage Capacity

This information is presented on 18 maps showing individual basins or basin groupings. Figure 5 is an index map showing the relative locations of the 18 basin groupings featured in the guide. The configuration and location of basins shown on Figure 5 were taken from "California's Groundwater," published by the Department of Water Resources as Bulletin Number 118, in 1975. The numbering system shown on Figure 5 is arbitrarily assigned for this guide and generally progresses from north to south and west to east. The individual basin maps are provided on the following pages. Basin boundaries and descriptive information have been provided by the basin managers unless otherwise noted. A contact list of basin managers is included at the end of this report.



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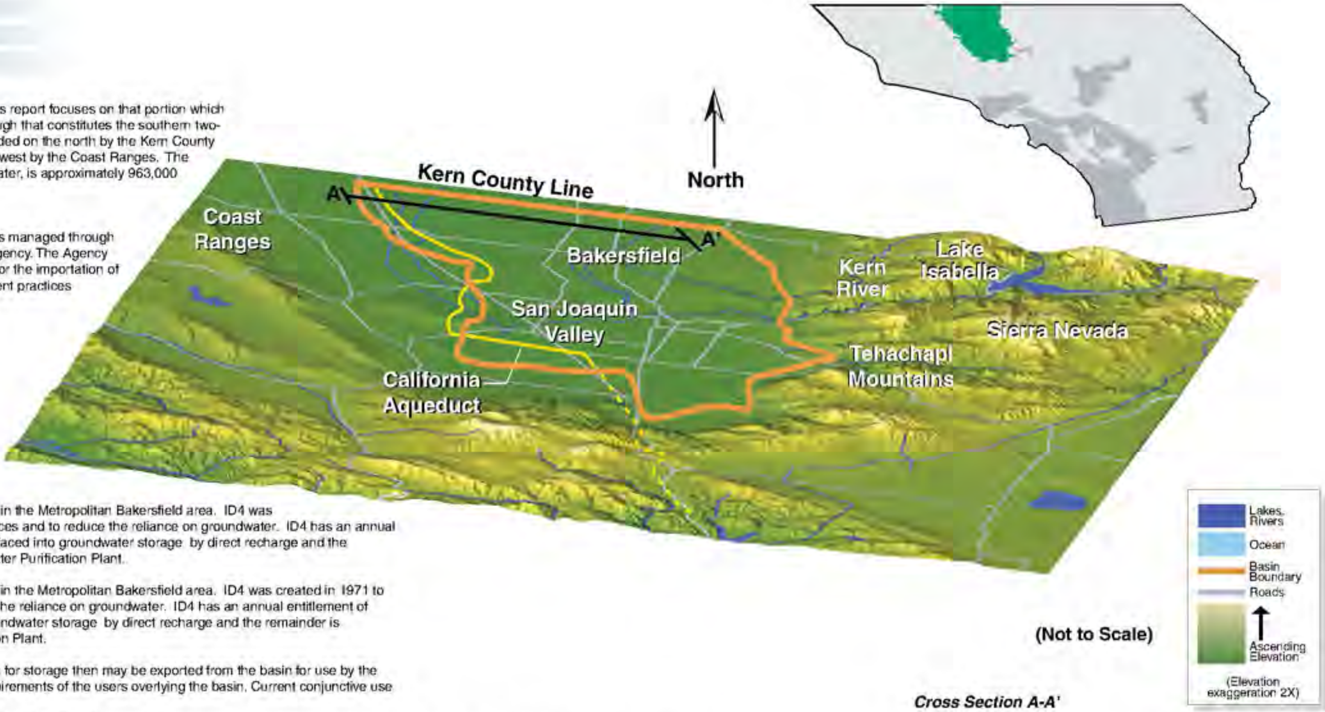
13. Upper Santa Margarita Watershed Basins
14. San Diego County Basins
15. Mojave River Basin
16. Hayfield Basin
17. Cadiz Valley Basin
18. Coachella Valley Basin

Figure 5
Index Map Showing the Relative Location of Basin Groupings Featured in the Guide

1. Kern County Basin



Location
The Kern County Groundwater Basins are made up of many differing geologic and climatic areas. This report focuses on that portion which occupies the southern San Joaquin Valley, which is a broad alluvial, northwest-trending structural trough that constitutes the southern two-thirds of the Central Valley. The Basin is located within the Tulare Lake hydrologic region and is bounded on the north by the Kern County line, on the east by the Sierra Nevada foothills, on the south by the Tehachapi Mountains, and on the west by the Coast Ranges. The principal watershed is drained by the Kern River. Surface area of the Basin overlying usable groundwater, is approximately 963,000 acres (1,505 square miles).

Basin Management
The Central Valley portion of the Kern County Groundwater Basin is an un-adjudicated Basin, which is managed through cooperative programs of individual Water Districts, the County of Kern, and the Kern County Water Agency. The Agency serves as a local contracting entity for the State Water Project (SWP). One of the primary purposes for the importation of SWP water into Kern County is to improve groundwater conditions within the Basin. Water management practices exercised by the Agency, the County, the City of Bakersfield and other Districts include the following:

- Groundwater recharge for overdraft correction and banking
- Importation to meet annual water requirements, and for conjunctive use and banking
- Replenishment
- Determination of groundwater storage
- Administration of water well ordinance
- Coordination with land use planning
- Controlling saline water intrusion
- Identification and management of recharge areas
- Groundwater quality and level monitoring
- Administration of groundwater quality and level databases

The Agency also administers Improvement District No. 4 (ID4), a successful conjunctive use program in the Metropolitan Bakersfield area. ID4 was created in 1971 to provide a supplemental surface water supply to augment local groundwater resources and to reduce the reliance on groundwater. ID4 has an annual entitlement of approximately 83,000 acre-feet from the SWP, approximately 60% to 70% of which is placed into groundwater storage by direct recharge and the remainder is delivered for urban use in-lieu of pumping groundwater through the Henry C. Garnett Water Purification Plant.

The Agency also administers Improvement District No. 4 (ID4), a successful conjunctive use program in the Metropolitan Bakersfield area. ID4 was created in 1971 to provide a supplemental surface water supply to augment local groundwater resources and to reduce the reliance on groundwater. ID4 has an annual entitlement of approximately 83,000 acre-feet from the SWP, approximately 60% to 70% of which is placed into groundwater storage by direct recharge and the remainder is delivered for urban use in-lieu of pumping groundwater through the Henry C. Garnett Water Purification Plant.

Groundwater banking programs differ from conjunctive use in that water may be imported to the basin for storage then may be exported from the basin for use by the entity banking the water. Conjunctive use programs typically are designed to help meet the water requirements of the users overlying the basin. Current conjunctive use and banking programs include the following programs for overlying users and bankers:

Banking Programs

NAME	STORAGE (MAF)	ANNUAL YIELD (AF/Y)
Kern Water Bank Authority Banking Project	1	287,000
Agency Pioneer Recharge and Recovery Project	.4	98,000
Joint Agency and Berrenda Mesa Water District Banking Project	.2	46,000
Arvin-Edison Water Storage District/ MWD Banking Project	.25	40,000
City of Bakersfield - 2800 Acre Spreading Grounds	.8	46,000
Semitropic Water Storage District Banking Project with Metropolitan Water District Water, Alameda County Water Agency, Santa Clara Water District District, Vidler Water Company, Zone 7 Water Agency	1	223,000
Buena Vista Water Storage District and West Kern Water District Recharge and Recovery Projects	.25	45,000

Overlying Use Programs

NAME	DEWATERED STORAGE (MAF)	ANNUAL WATER REQUIREMENTS (AF/Y)
Arvin-Edison WSD	2.9	337,000
Buena Vista WSD	0.3	134,000
Cawelo WD	0.6	142,000
Delano-Earlimart ID	0.1	32,000
Henry Miller	.05	60,000
ID#4	.3	119,000
Kern Delta WD	0.7	412,000
North Kern WSD	0.9	212,000
Rosedale-Rio Bravo WSD	0.4	111,000
Semitropic WSD	2.2	544,000
Shafter Wasco ID	.4	116,000
Southern San Joaquin MUD	0.4	181,000
Wheeler Ridge - Maricopa Water Storage District	2.0	346,000
Kern-Tulare and Rag Gulch Water Districts	0.5	58,700

Available Storage
De-watered storage space is estimated to be about 12 million AF. Storage space used for current Banking Projects is about 4 million AF. Remaining de-watered space available for additional banking and overdraft correction is estimated to be 8 million AF.

Present Operational Safe Yield
The natural recharge of the Basin is about 180,000 AF/Y.
The increase in operational yield for overlying users due to importation and conjunctive use is about 2 million AF/Y.

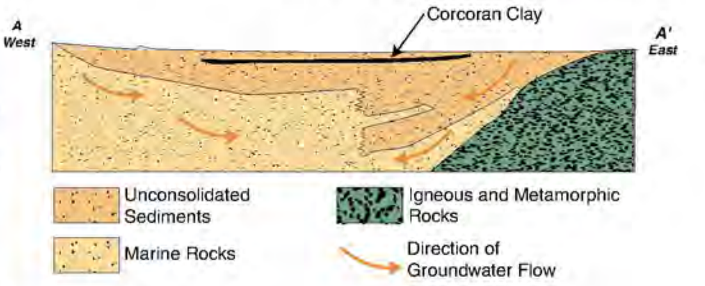
The maximum dry year recovery capacity of the Banking Projects is currently about 785,000 AF/Y provided enough water can be imported and placed into storage for recovery. The future increase in dry year recovery capacity is about 284,000 AF/Y provided increases in delta diversions or other surface supplies are made available.

Basin Sediments
Sediments that comprise the Basin are unconsolidated deposits of Tertiary and Quaternary age. These deposits include alluvium, lacustrine, deltaic, and flood-basin deposits consisting of sand and gravel with thin lenses of silt and clay, as well as the Tulare and Kern River Formations. In northeastern Kern County, some water production is derived from the Santa Margarita and Olcese Formations. Unconsolidated sediments overlie the igneous and metamorphic basement complex of the Sierra Nevada to the east and marine rocks of the Coast Ranges to the west.

In the eastern third of the Basin, groundwater occurs primarily under unconfined and semi-confined conditions. In the north - central portion of the Basin the Corcoran Clay is present at depths from 300 to 650 feet. Below the Corcoran Clay, groundwater is confined.

The major sources of natural recharge are infiltration of rainfall on the valley floor and percolation of runoff from the Kern River and adjacent mountains. The Basin also receives imported water from the SWP and Federal CVP and return flow from applied water.

Cross Section A-A'



(From USGS, 1965, Professional Paper 1401-C)

Conjunctive Use Potential
The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 2,000,000 AFY. Additionally, the survey indicated the potential to store up to 8,000,000 AF of water for use in dry years and a potential increase in basin operational yield of 284,000 AFY.

2. Tehachapi/Cummings Basin

Location
The Tehachapi/Cummings Groundwater Basin is located between the southern end of the Sierra Nevada and the northeastern side of the Tehachapi Mountains. The Tehachapi/Cummings Groundwater Basin includes the Tehachapi Basin, Cummings Basin, and Brite Basin. Brite Basin is generally located between the Cummings and Tehachapi Basins but is not shown on the map because it lacks distinct boundries. The basin is bounded on all sides by crystalline bedrock. The surface areas of the basins are as follows:

- Tehachapi Basin, 99 square miles (63,500 acres)
- Cummings Basin, 38 square miles (24,600 acres)
- Brite Basin, 12 square miles (7,900 acres)

Basin Management
The basin is adjudicated and is managed by the Tehachapi-Cummings Water District (Watermaster).

Available Storage
Not available as of July 2000.

Present Operational Safe Yield
The present operational safe yield of Tehachapi Basin is 5,500 acre-feet per year (AFY) and 4,090 AFY for Cummings Basin, and 500 AFY for Brite Basin (not shown on map), yielding a combined total operational safe yield of 10,090 AFY.

Basin Sediments
Basin sediments consist of unconsolidated deposits underlain by marine rocks.

Conjunctive Use Potential
The Tehachapi-Cummings Water District is currently conducting studies to determine the conjunctive use potential of the basin.

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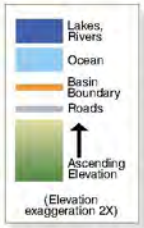
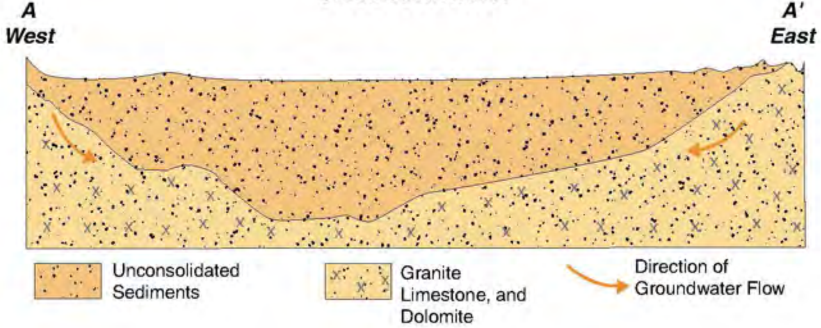


Cross Section A-A'



3. Ventura County Basins

Locations
The groundwater basins of Ventura County are located beneath the Oxnard Coastal Plain and in the surrounding river valleys. The four largest valleys consist of the Santa Clara River Valley, Pleasant Valley, Arroyo Santa Rosa Valley, and Las Posas Valley. In total, there are 32 groundwater basins in Ventura County. Of these 32 basins, the 14 basins having total storage capacities in excess of 50,000 acre-feet (AF) each are listed and shown on this basin map.

Basin Management
The groundwater basins are generally not managed by a particular agency with the following noted exceptions:

Basin	*Management Structure*
Oxnard Coastal Plain and Forebay	State Legislation and Ordinances
Fillmore Basin	AB-3030 Plan and United Water Conservation District
Santa Paula Basin	United Water Conservation District
Piru Basin	United Water Conservation District
Arroyo Santa Rosa Basin	State Legislation and Ordinances
North Las Posas Basin	State Legislation and Ordinances

The Calleguas Municipal Water District (CMWD) and the Metropolitan Water District of Southern California (MWD), are currently developing a conjunctive use program in the North Las Posas Basin. The program calls for MWD to finance up to 30 injection and pumping wells in the basin. MWD will have the right to store up to 210,000 AF of water in the basin. During times of need, MWD will decrease its surface water deliveries to CMWD and replace that water with stored water extracted from the North Las Posas Basin.

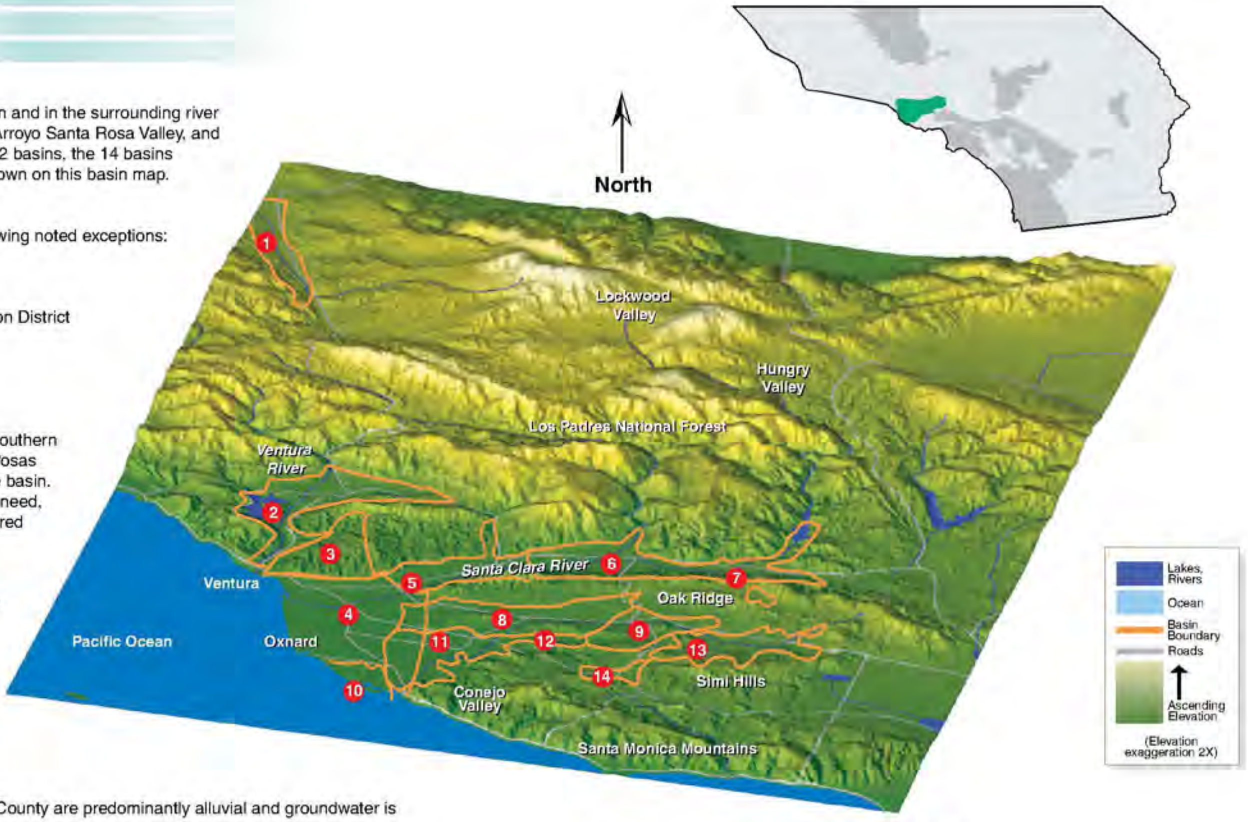
Available Storage
The freshwater storage capacity of all Ventura County groundwater basins is 32,000,000 AF. Approximately 27,400,000 AF are currently in storage with 500,000 AF of available storage potential.

Present Operational Safe Yield
The present operational safe yield of the Basins of Ventura County is 176,538 acre-feet per year (AFY). Future operational yield is anticipated to increase by 87,600 AFY.

Basin Sediments
Sediments that comprise the groundwater basins underlying the river valleys of Ventura County are predominantly alluvial and groundwater is typically unconfined.

Sediments that comprise the larger groundwater basins of Ventura County are predominantly alluvial. Groundwater in these basins is both confined and unconfined. Several smaller basins in this area are comprised of sedimentary rocks, limited volcanics, and sandstone or siltstone. These smaller basins have limited storage potential.

Conjunctive Use Potential
The results of AGWA's survey indicate the potential to store up to 500,000 AF of water for use in dry years and a potential increase in basin operational yield of 87,600 AFY.



(Not to Scale)

Groundwater Basins

① Cuyama River	⑧ North Las Posas
② Ojai & Ventura River Valley	⑨ South Las Posas
③ Mound	⑩ Mugu Forebay
④ Oxnard Coastal Plain & Forebay	⑪ Pleasant Valley
⑤ Santa Paula	⑫ Arroyo Santa Rosa
⑥ Fillmore	⑬ Simi Valley
⑦ Piru	⑭ Thousand Oaks

4. San Fernando Valley Basins

Location

The groundwater basins of the San Fernando Valley, located within the Upper Los Angeles River Area (ULARA) watershed, consist of the following:

- Sylmar Basin
- Verdugo Basin
- San Fernando Basin

The surface area of the ULARA watershed is approximately 514 square miles or 327,000 acres.

Basin Management

The groundwater basins are adjudicated under the auspices of the ULARA Watermaster. The basins were adjudicated on January 29, 1979 under the case referred to as the San Fernando Judgement.

Available Storage

The fresh water storage capacity of the San Fernando basins ranges from 0 to 550,000 acre-feet (AF). The actual amount of water in storage is determined by the ULARA Watermaster. Annual natural recharge and artificial recharge is approximately 44,000 and 61,000 acre-feet per year (AFY), respectively.

Present Operational Safe Yield

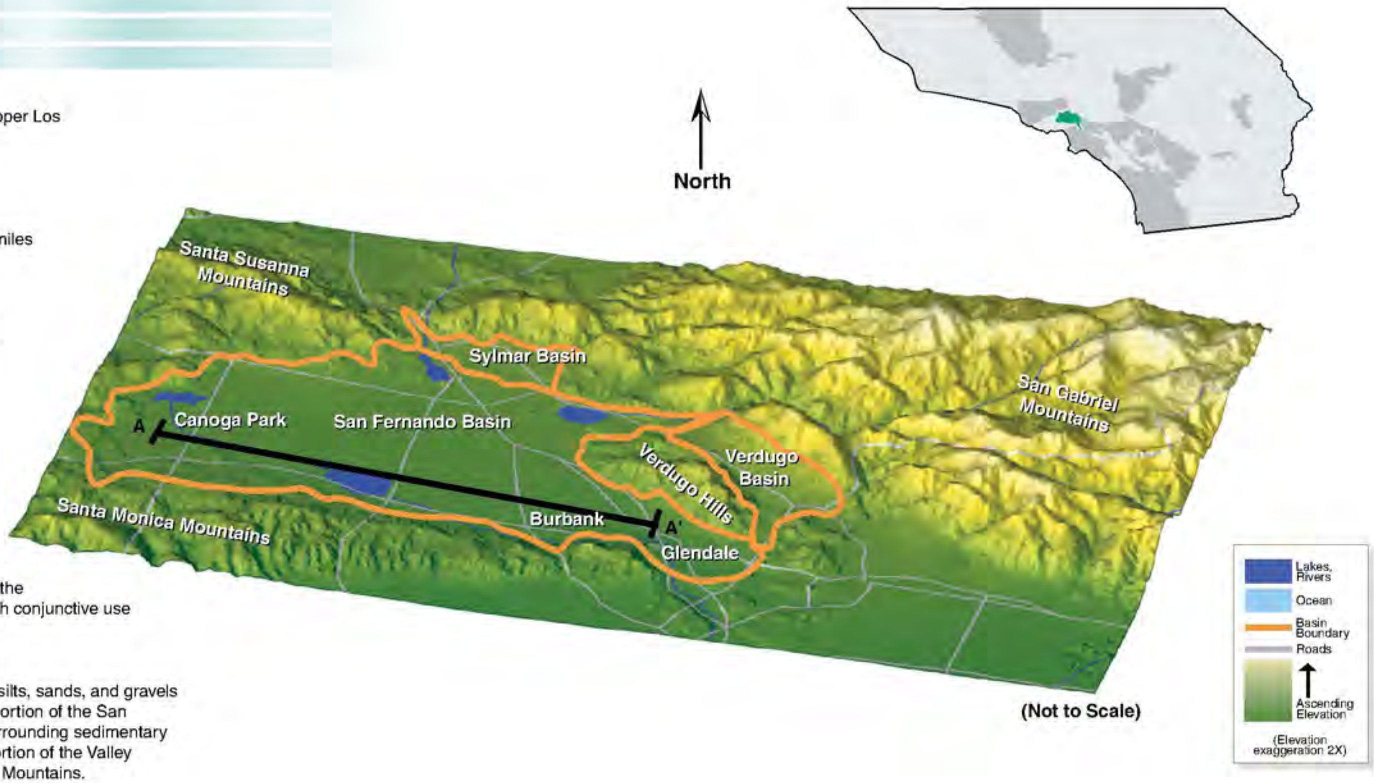
The present operational safe yield of the San Fernando Valley basins is approximately 105,000 AFY, providing approximately 15-20% of the water supply for the cities of Burbank, Glendale, and Los Angeles. Through conjunctive use programs, these cities have stored approximately 356,000 AF.

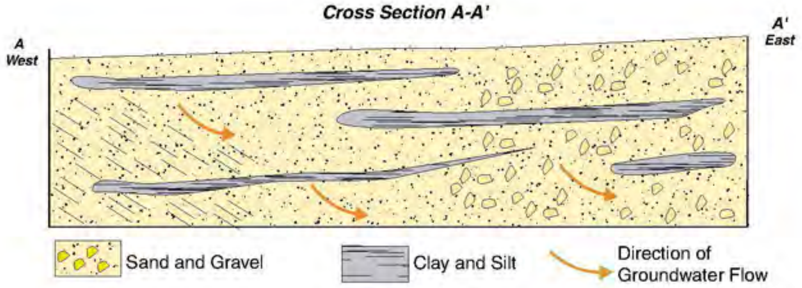
Basin Sediments

The alluvial sediments in the San Fernando Valley are a mixture of clays, silts, sands, and gravels that extend to a depth of at least 1,000 feet in some areas. The western portion of the San Fernando Valley is composed of fine-grained material derived from the surrounding sedimentary rocks in the Santa Susanna and Santa Monica Mountains. The eastern portion of the Valley consists of coarse sand and gravel deposits derived from the San Gabriel Mountains.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 43,700 AFY. Additionally, the survey indicated the potential to store up to 150,000 AF of water for use in dry years and a potential increase in basin operational yield of 27,300 AFY.




Cross Section A-A'

5. Raymond Basin

Location

The Raymond Groundwater Basin is located in the central portion of Los Angeles County. The basin is bounded on the north by the San Gabriel Mountains, on the south and east by the Raymond fault and adjacent San Gabriel Valley, and on the west by the San Rafael Hills and the Verdugo Basin. The entire basin lies within the watershed of the Los Angeles River. Principal streams include the Arroyo Seco, Eaton Wash, and Santa Anita Wash. The surface area of the Basin is 40 square miles or 25,600 acres.

Significant faults in the Basin include the following:

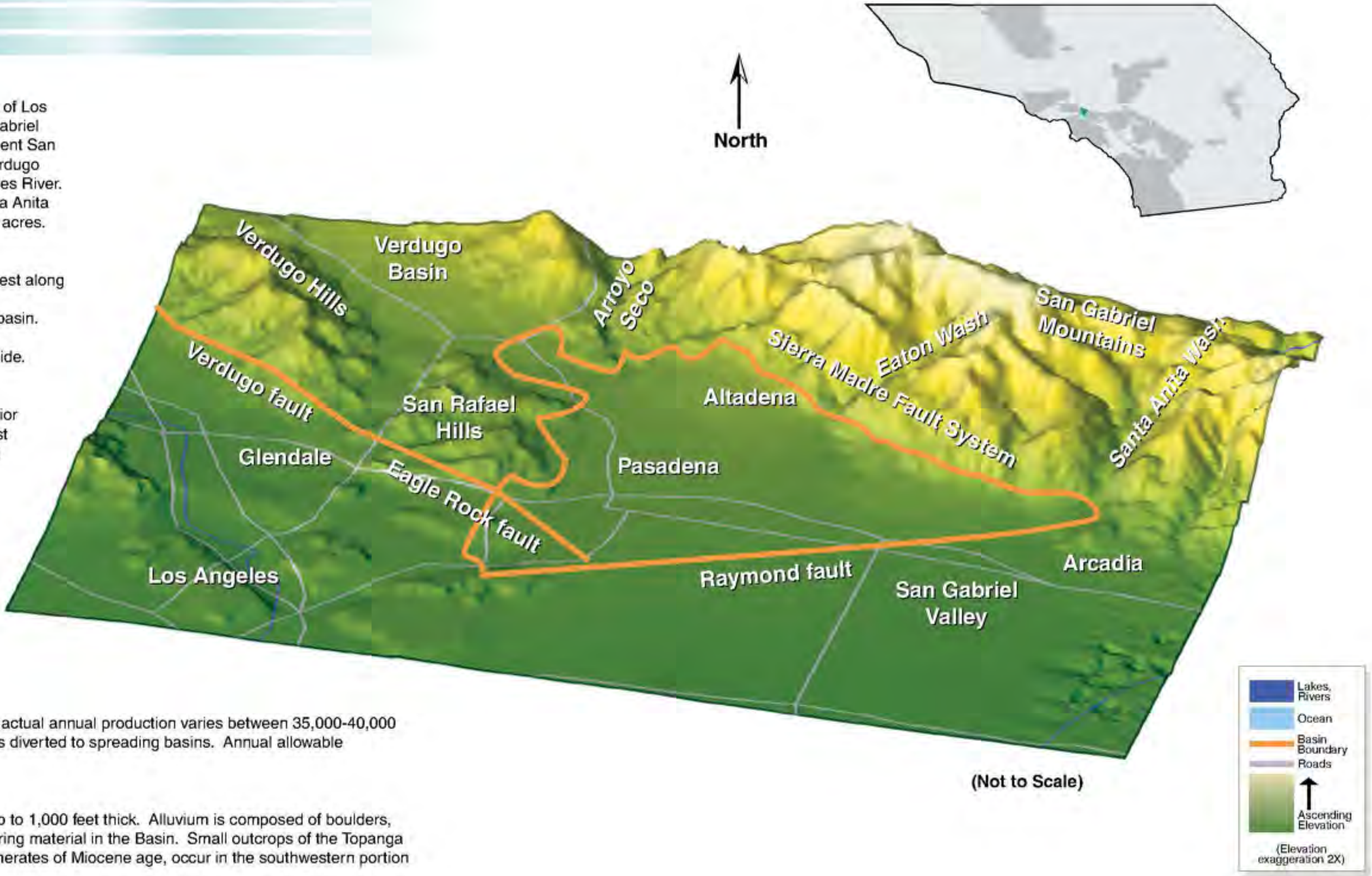
- Sierra Madre Fault System that trends southeast to northwest along the base of the San Gabriel Mountains.
- Raymond fault, which forms the southern boundary of the basin.
- Eagle Rock fault in the southwestern part of the basin.
- Eaton Wash fault, which occurs intrabasin on the eastern side.

Basin Management

The Raymond Basin was adjudicated in 1944, following the Superior Court Judgment Pasadena v. Alhambra, et al. This marked the first groundwater adjudication in the State of California. The Raymond Basin Management Board governs the basin.

Available Storage

The fresh water storage capacity of the basin is a minimum of 250,000 acre-feet (AF). As of June 30, 1999, approximately 56,000 AF of water was stored in the Basin by various parties and approximately 194,000 AF of unused storage was available. Raymond Basin recently began implementation of a conjunctive use program with Metropolitan Water District to store 75,000 AF of water for use during dry years.



Present Operational Safe Yield

The present operational safe yield of the Basin is 30,622 AFY, but actual annual production varies between 35,000-40,000 AFY depending upon the amount of local storm runoff water that is diverted to spreading basins. Annual allowable extractions vary between 35,000-43,000 AFY.

Basin Sediments

Raymond Basin is underlain by unconsolidated alluvial deposits up to 1,000 feet thick. Alluvium is composed of boulders, gravel, sand, silt, and clay, and constitutes the principal water-bearing material in the Basin. Small outcrops of the Topanga Formation, which consists of consolidated sandstone and conglomerates of Miocene age, occur in the southwestern portion of the Basin.

Conjunctive Use Potential

The results of AGWA's survey indicate the potential to store an additional 144,000 AF of water for use in dry years.

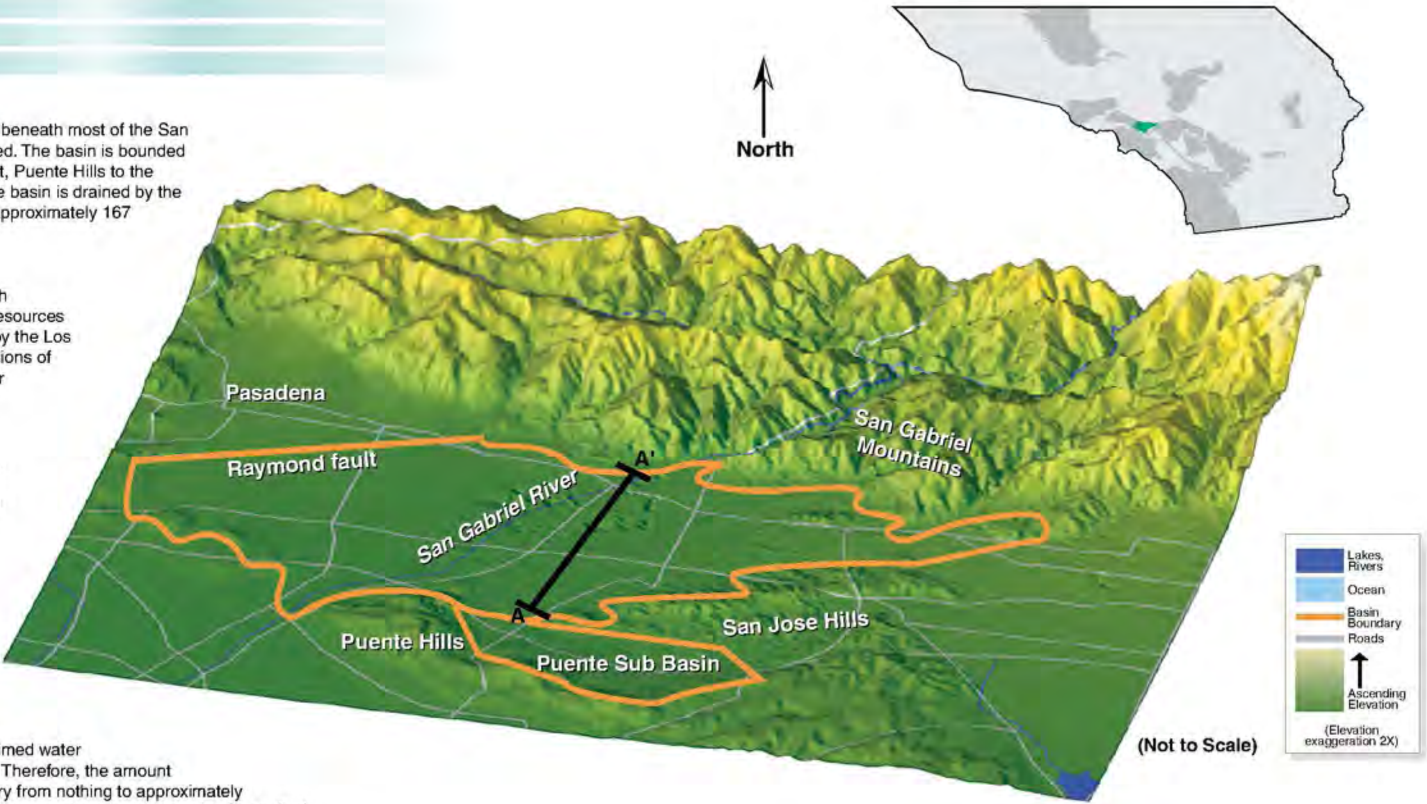
6. Main San Gabriel Basin

Location
The Main San Gabriel Basin underlies eastern Los Angeles County, beneath most of the San Gabriel Valley and a portion of the upper San Gabriel River watershed. The basin is bounded by the San Gabriel Mountains to the north, San Jose Hills to the east, Puente Hills to the south, and by a series of hills and the Raymond fault to the west. The basin is drained by the San Gabriel River and Rio Hondo. The surface area of the Basin is approximately 167 square miles or 106,880 acres.

Basin Management
The Main San Gabriel Basin Watermaster is the agency charged with administering adjudicated water rights and managing groundwater resources within the basin. The Watermaster, a nine-person board appointed by the Los Angeles County Superior Court, administers and enforces the provisions of the Judgement that established water rights and the responsibility for efficient management of the quantity and quality of the basin's groundwater.

The Puente Subbasin is located in the southeast portion of the map, and is hydraulically connected to the basin, with no barriers to groundwater movement. However, the Puente Subbasin is not within the legal jurisdiction of the Watermaster, and is thus considered a separate entity for management purposes.

Available Storage
The freshwater storage capacity of the basin is estimated to be about 8.6 million acre-feet (AF). Of this amount, approximately 400,000 acre-feet is usable for water supply. Historically, the maximum utilization of basin storage has been 900,000 AF; however, the storage available for imported and reclaimed water is dependent upon the water surface elevation at the Baldwin Park Key Well. When the water surface elevation exceeds 250 feet, neither imported nor reclaimed water can be placed in storage, except in the eastern portion of the basin. Therefore, the amount of storage generally available for imported or reclaimed water will vary from nothing to approximately 400,000 AF. To date, 170,000 AF has already been committed to various producers and agencies for cyclical storage.



(Not to Scale)

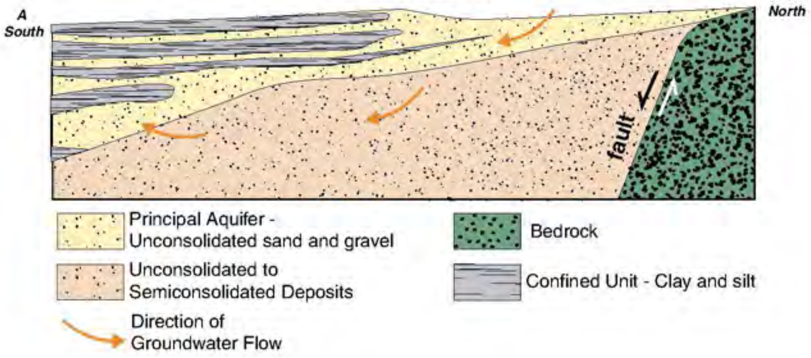
Present Operational Safe Yield
The operational safe yield of the basin is determined annually by the Watermaster and has ranged from a low of 140,000 AF to a high of 230,000 AFY averaging almost 200,000 AFY since 1973-74. The operational safe yield for fiscal year 2000-01 is 220,000 AFY.

Basin Sediments
The principal water-bearing formations of the basin are unconsolidated and semi-consolidated sediments that range from fine-grained sands to coarse gravel.

The major sources of groundwater recharge are infiltration of rainfall on the valley floor and percolation of runoff in unlined storm channels and off-channel spreading grounds. The basin also receives imported water and return flow from applied water.

Conjunctive Use Potential
The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 76,000 AFY. Additionally, the survey indicated the potential to store up to 400,000 AF of water for use in dry years and a potential increase in basin operational yield of 187,000 AFY.

Cross Section A-A'



7. Los Angeles Coastal Plain Basins

Location

The Los Angeles Coastal Plain is underlain by a structural basin formed by folding of the consolidated sedimentary, igneous, and metamorphic rocks that underlie the basin at great depths. Although the subsurface structure of the coastal plain is complex, two major northwest-trending troughs, which are separated for most of their length by the Newport-Inglewood Fault Zone (uplift), contain the sediments that compose the aquifer system. These sediments are as thick as 30,000 feet in some areas.

The Los Angeles Coastal Plain is bordered by the Santa Monica Mountains to the north, the Palos Verdes Hills and Pacific Ocean to the west, the Puente, Elysian, Repetto, and Merced Hills to the northeast, and the Los Angeles/Orange County line to the east and southeast. Primarily the Los Angeles and San Gabriel River systems drain the Coastal Plain.

The Coastal Plain is divided into four groundwater basins:

- The **Central Basin** extends over most of the coastal plain, east and northeast of the Newport-Inglewood Uplift. The basin occupies approximately 278 square miles (177,920 acres) and contains unconfined and confined alluvial aquifers (further subdivided into the Montebello Forebay, Los Angeles Forebay, Whittier Area, and Central Basin Pressure Area).

- The **West Coast Basin** extends southwesterly from the Newport-Inglewood Uplift to Santa Monica Bay, to the drainage divide on the Palos Verdes Hills, and to San Pedro Bay. The basin occupies approximately 172 square miles (110,080 acres) and contains mostly confined alluvial aquifers.

- The **Santa Monica Basin** is bounded by the Santa Monica Mountains to the northwest, the Hollywood Basin to the northeast and east, the West Coast Basin to the south, and Santa Monica Bay to the west (further subdivided into the Coastal, Charnock, and Crestal sub-basins). The basin occupies approximately 46 square miles (29,440 acres) and contains mostly confined alluvial aquifers.

- The **Hollywood Basin**, which is approximately 16 square miles (10,240 acres) in size, is an east-west syncline that lies between two branches of the Hollywood fault. The basin is bounded by the Newport-Inglewood Uplift on the west, the Elysian Hills on the east, the La Brea High to the south, and the Santa Monica Mountains to the north. The aquifers are both confined and unconfined.

Basin Management

The Central and West Coast Basins are both adjudicated. The California Department of Water Resources is the court-appointed Watermaster and the Water Replenishment District of Southern California has assumed the role of groundwater basin manager.

The Santa Monica and Hollywood Basins are neither adjudicated nor formally managed.

Total Stored Water	**Present Operational Safe Yield**	**Available Storage**
Central Basin - 13,800,000 AF	Central Basin - 217,367 AFY[1]	Central Basin - 789,000 AF
West Coast Basin - 6,500,000 AF	West Coast Basin - 64,468 AFY[1]	West Coast Basin - 300,000 AF
Santa Monica Basin - 1,100,000 AF	Santa Monica Basin - 100 AFY[2]	Santa Monica Basin - not available
Hollywood Basin - 200,000 AF	Hollywood Basin - 4,400 AFY[2]	Hollywood Basin - not available

Basin Sediments

Deposition in the Los Angeles Coastal Plain has been largely influenced by sea-level fluctuations combined with alluvial sedimentation related to ancestral river systems that traversed the Coastal Plain. Water-bearing sediments are primarily of Pleistocene age and 11 aquifers have been named:

- Semi-perched
- Gaspur
- Artesia
- Exposition
- Gage
- Gardena
- Hollydale
- Jefferson
- Lynwood
- Silverado
- Sunnyside

Groundwater also occurs in the Pliocene Pico Formation, but generally at insufficient quantities and quality to supply production wells.

Each aquifer consists of a distinct layer of water-yielding sand and gravel usually separated from other sand and gravel beds by clay and silt confining units. In many places, however, the water-yielding sediments of the different aquifer may be in direct hydraulic contact with each other, or the intervening confining units contain sufficient sand and gravel to allow water to pass between adjacent aquifers.

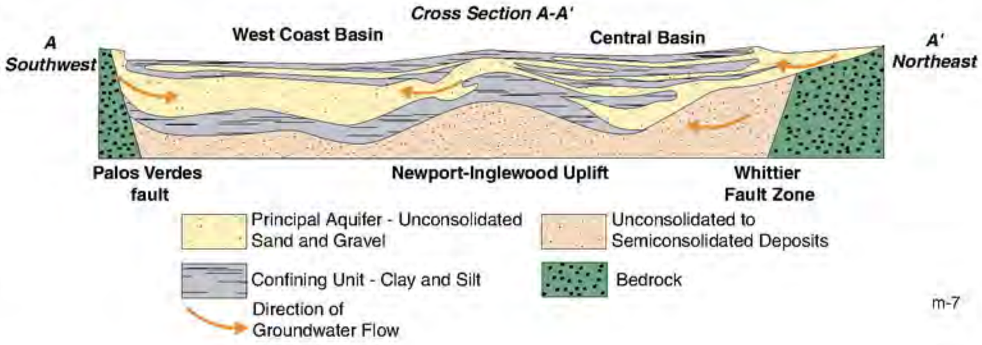
A layer of clay and silty clay of marine and continental origin, which is at or near the land surface over most of the coastal plain, is a competent confining unit where it does not contain large amounts of sand and gravel. This confining unit ranges from less than 1 foot to about 180 feet in thickness. In the Los Angeles and Montebello Forebays, the confining unit is not present, and groundwater is under unconfined, or water table, conditions.

Freshwater is contained within deposits that range in age from Holocene to late Pliocene. The main freshwater body extends from depths of less than 100 to about 4,000 feet. At greater depths, the water is saline and unpotable. The freshwater body is thickest near the axis of the troughs where water-yielding sediments reach their greatest thickness, and thinnest where these sediments overlie anticlines or become thin at the margins of the aquifer system.

The Montebello and Los Angeles Forebays are areas of groundwater recharge, whereby deep aquifers are hydraulically connected to the ground surface and further characterized by the absence of the Bellflower aquiclude (a thick silt/clay layer). The Pressure Area is typified by the presence of the Bellflower aquiclude near the ground surface, thereby preventing groundwater recharge.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 54,000 AFY. Additionally, the survey indicated the potential to store up to 1,089,000 AF of water for use in dry years and a potential increase in basin operational yield of 54,300 AFY.



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[1] Adjudicated amount

[2] DWR Bulletin 104-B, 1962 "Safe Yield Determinations", Table 27

8. Orange County Coastal Plain Basin

Location
The Orange County groundwater basin underlies the Orange County Coastal Plain, beneath the broad lowlands known as the Tustin and Downey Plains. The basin is bounded by the Los Angeles County Line, Coyote Hills, and Chino Hills to the north, the Pacific Ocean and Newport-Inglewood Uplift to the west, the Santa Ana Mountains to the east, and non-water bearing formations that occupy the southern half of Orange County to the south. The surface area of the basin is approximately 350 square miles or 224,000 acres.

Basin Management
The basin is managed by the Orange County Water District (OCWD) and is not adjudicated.

OCWD was created in 1933 by California State legislation to manage and protect the vast groundwater basin under north central Orange County. Since that time, OCWD has tripled the yield of the basin through a tradition of innovation that includes expansion and improvements to recharge facilities, employment of well head and other treatment technologies, water research, conservation and reclamation projects. OCWD's Water Factory 21, which remains a model for water reclamation around the world, provides millions of gallons of water each day to create a fresh water barrier against seawater intrusion and to replenish the basin. OCWD's Green Acres irrigation and industrial water project frees up thousands of acre-feet of potable water each year.

OCWD supplies reliable, high-quality groundwater to more than 23 cities and water agencies serving 2 million residents. The basin is recharged primarily from the Santa Ana River and to a lesser extent from imported water purchased from the Metropolitan Water District of Southern California. OCWD monitors the groundwater extracted each year to ensure that the basin is not overdrawn and carries out an assessment program to pay for operating expenses and the cost of imported replenishment water.

OCWD has one of the most sophisticated groundwater protection programs in the world using an array of monitoring wells. The wells provide input to a three-layer groundwater model of the basin that is used for basin management.

Available Storage
The freshwater storage capacity of the basin is 1,000,000 AF and there are 300,000 AF of available storage.

Present Operational Safe Yield
The present operational safe yield of the basin is 350,000 AFY and this is expected to increase in the future by 130,000 AF.

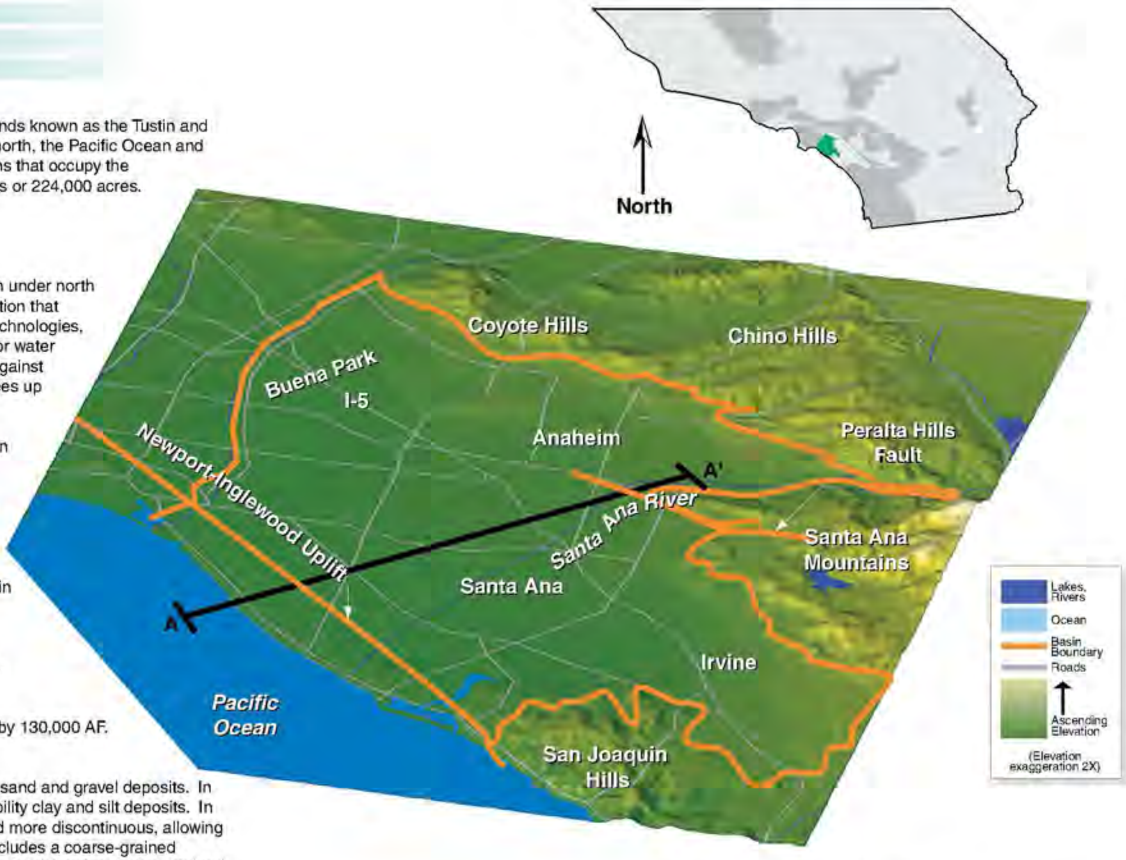
Basin Sediments
The aquifers comprising the basin extend over 2,000 feet deep and form a complex series of interconnected sand and gravel deposits. In the coastal and central portions of the basin, these deposits are more separated by extensive lower permeability clay and silt deposits. In the inland area of the basin, generally northeast of Interstate 5, the clay and silt deposits become thinner and more discontinuous, allowing groundwater to flow more easily between shallow and deeper aquifers. The northeast portion of the basin includes a coarse-grained unconfined forebay area. Moving toward the coast, the basin becomes confined with finer-grained sediments overlying the coarser-grained aquifer.

The basin is divided into two hydrologic components, the forebay and pressure areas. The forebay/pressure boundary generally delineates the area where surface water nor shallow groundwater can/cannot move downward in significant quantities. The boundary represents a transition zone where low-permeability clay and silt deposits increasingly occur in near-surface sediments southwest of the boundary.

The forebay refers to the area of intake or recharge, where the majority of recharge to the basin occurs primarily by direct percolation of Santa Ana River water. The forebay area, underlying most of the cities of Anaheim, Fullerton, and Villa Park, and portions of the cities of Orange and Yorba Linda, is characterized by highly permeable sands and gravel with few clay and silt deposits.

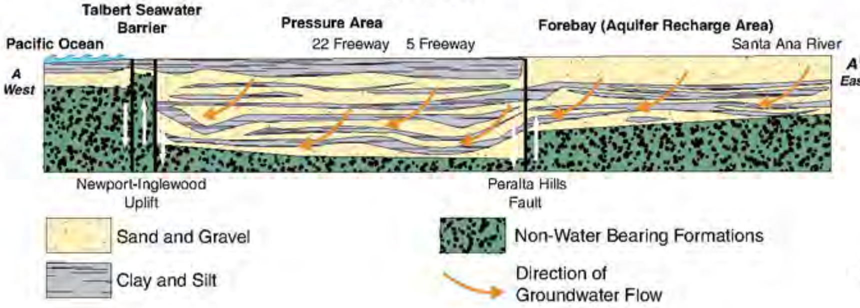
The pressure area is defined as the area in the basin where surface water and near surface groundwater are prevented from percolating in large quantities into the producible aquifers by clay and silt layers at shallow depths. Most of the central and coastal portions of the basin fall within the pressure area.

Conjunctive Use Potential
The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 150,000 AFY. Additionally, the survey indicated the potential to store up to 300,000 AF of water for use in dry years and a potential increase in basin operational yield of 130,000 AFY.



(Not to Scale)

Cross Section A-A'



9. Six Basins

Location
Six Basins is comprised of the following groundwater basins:

- San Antonio Canyon Basin
- Live Oak Basin
- Upper Claremont Heights Basin
- Lower Claremont Heights Basin
- Pomona Basin
- Ganesha Basin

Six Basins underlie the cities of Claremont, La Verne, and Pomona in northeastern Los Angeles County and northwestern San Bernardino County.

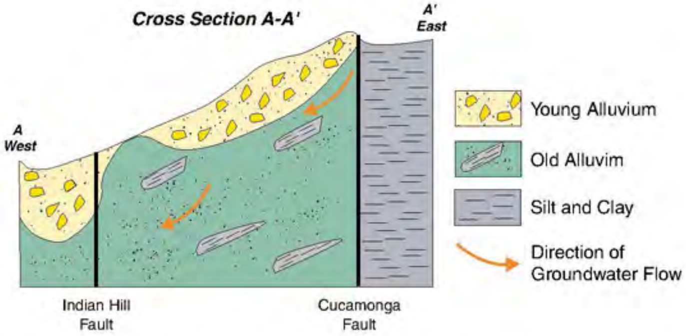
Basin Management
The Six Basins Watermaster was formed by a stipulated agreement, the final Judgement becoming effective January 1999. The judgement establishes groundwater rights and provides a structure for the operation and management of the Six Basins.

Available Storage
The available freshwater storage capacity of the aquifer is 30,000 acre-feet (AF).

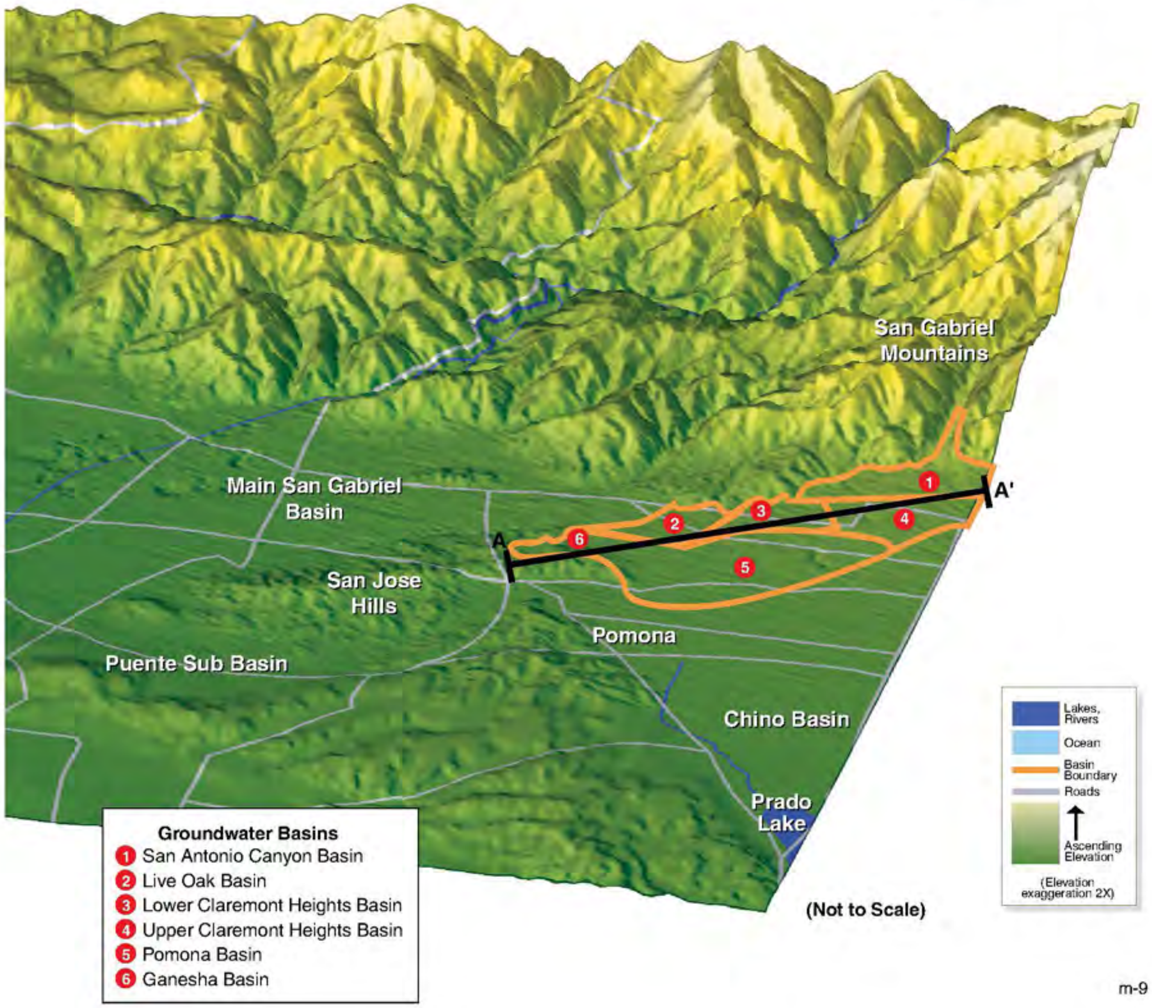
Present Operational Safe Yield
The present operational safe yield of Six Basins is 24,000 acre-feet per year (AFY).

Basin Materials
Aquifer materials consist primarily of sand and gravel deposited as alluvial fans. Silt and clay deposits increase with distance away from the San Gabriel Mountains. Basin depth generally increases with distance away from the San Gabriel Mountains, but is complicated by faulting.

Cross Section A-A'



Conjunctive Use Potential
The results of AGWA's survey indicate the potential to store up to 30,000 AF of water for use in dry years and a potential increase in basin operational yield of 30,000 AFY.



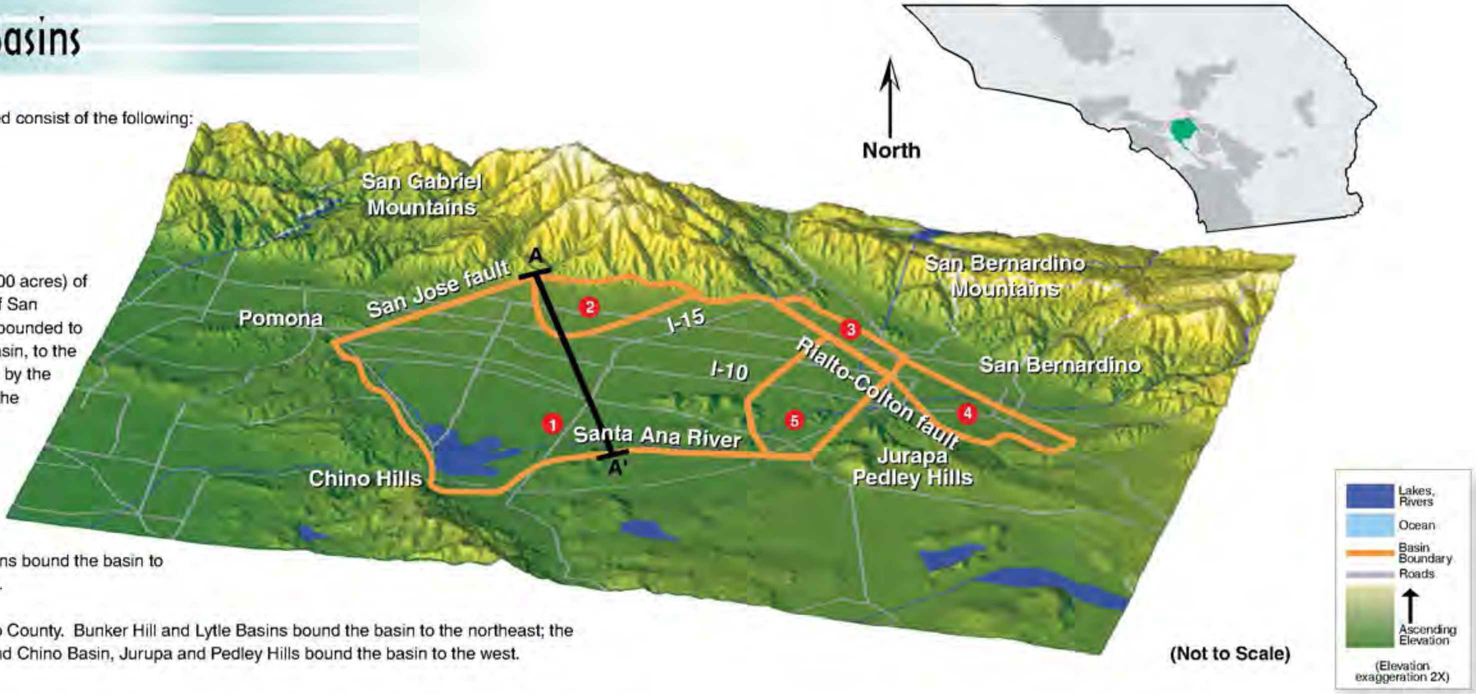
(Not to Scale)

10. Upper Santa Ana River Basins

Location

The groundwater basins of the upper Santa Ana River watershed consist of the following:

- Chino Basin
- Cucamonga Basin
- Rialto Basin
- Colton Basin
- Riverside Basin



Chino Basin consists of approximately 235 square miles (154,400 acres) of the Upper Santa Ana River Watershed and underlies portions of San Bernardino, Los Angeles and Riverside Counties. The basin is bounded to the north by the San Gabriel Mountains and the Cucamonga Basin, to the south by the La Sierra area and the Temescal Basin, to the east by the Colton and Rialto basins, Jurupa Hills, and Pedley Hills, and to the west by the Chino Hills, Puente Hills, and the Pomona and Claremont basins.

Cucamonga Basin comprises approximately 22 square miles (14,000 acres) and is located at the base of the San Gabriel Mountains near the communities of Upland, Rancho Cucamonga, Etiwanda, and Fontana. The San Gabriel Mountains bound the basin to the north. The Red Hill fault bounds the basin on all other sides.

Rialto and Colton Basins are located in western San Bernardino County. Bunker Hill and Lytle Basins bound the basin to the northeast; the San Bernardino Mountains bound the basin to the northwest; and Chino Basin, Jurupa and Pedley Hills bound the basin to the west.

Basin Management

Chino Basin is an adjudicated basin managed by the Chino Basin Watermaster (Watermaster). The Watermaster was established under a judgement entered in the Superior Court of the State of California for the County of San Bernardino, entitled "Chino Basin Municipal Water District vs. City of Chino et al". The Basin has been operated as described in the 1978 judgement.

Cucamonga Basin was adjudicated in 1958 and is jointly managed by the Cucamonga County Water District and San Antonio Water Company. The Rialto and Colton Basins were adjudicated in 1961.

Available Storage

The unused storage capacity in Chino and Riverside-Colton Basins is 1,000,000 acre-feet (AF) and 98,000 AF, respectively. Cucamonga Basin has no unused storage capacity.

Present Operational Safe Yield

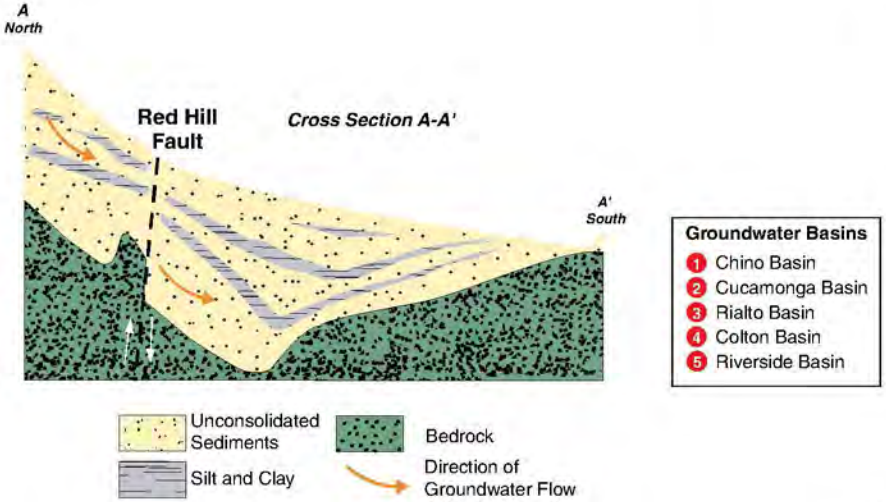
The present operational safe yield of Chino Basin is 145,000 acre-feet per year (AFY), and that of Cucamonga and Riverside-Colton Basins is about 14,000 to 22,000 and 9,000 AFY, respectively.

Basin Materials

Sediments in Chino Basin are alluvial in origin and derived from the surrounding San Bernardino and San Gabriel Mountains. Sediments are coarser in the northern part of the basin and the aquifer is unconfined. From north to south, the aquifer becomes finer-grained and semi-confined. Alluvial sediments also dominate in Cucamonga Basin, Rialto, and Colton Basins.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 43,000 AFY. Additionally, the survey indicated the potential to store up to 1,854,000 AF of water for use in dry years and a potential increase in basin operational yield of 47,000 AFY.



11. Bunker Hill Basin

Location

The Bunker Hill Groundwater Basin is located in San Bernardino County, and is partially overlain by the City of San Bernardino. The basin is bounded on the northeast by the San Andreas fault, on the southwest by the San Jacinto fault, on the southeast by the Crafton Hills fault, and on the northwest by the San Bernardino Mountains.

Basin Management

The basin is adjudicated. The San Bernardino Valley Municipal District (SBVWCD) Watermaster manages the basin.

Available Storage

The fresh water storage capacity of the basin is estimated at 1,432,000 AF. Currently, the basin is essentially full.

Present Operational Safe Yield

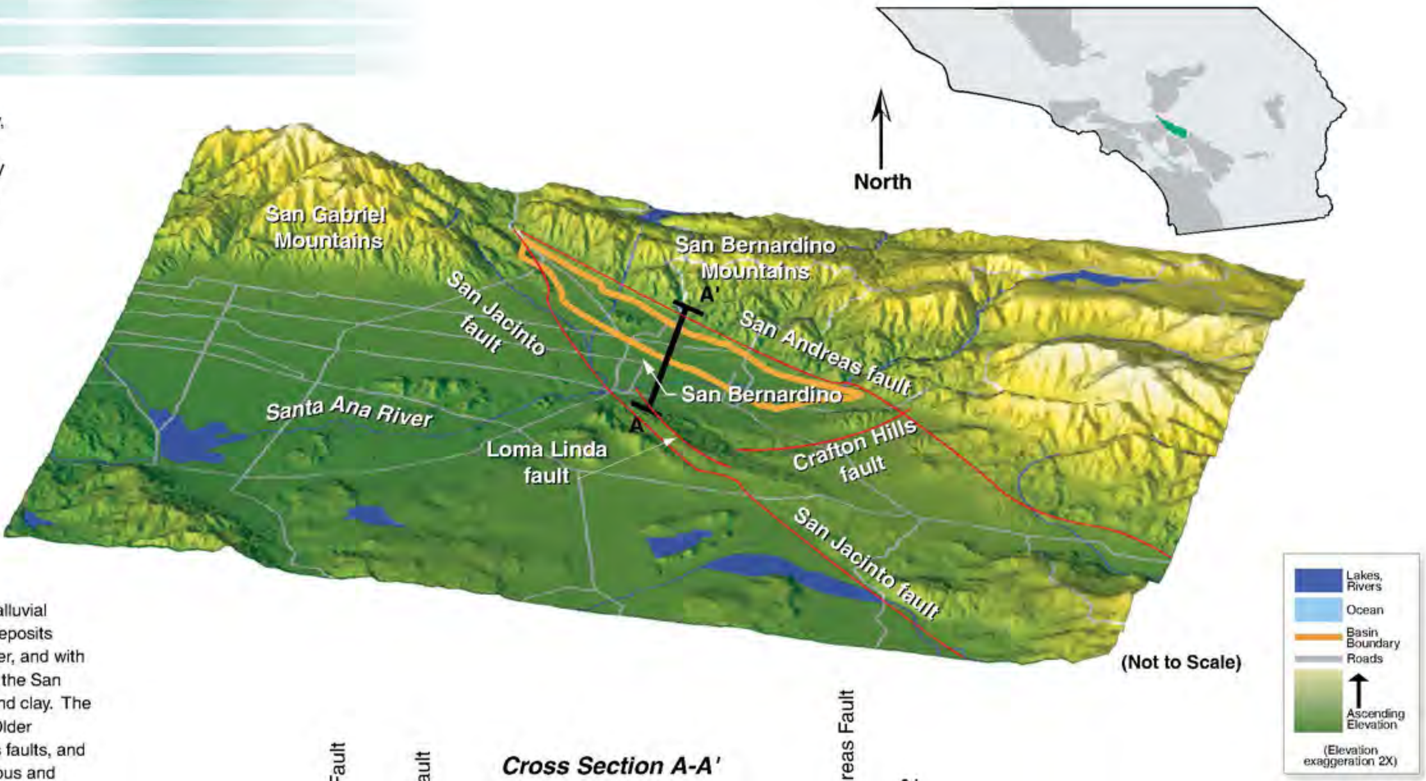
The present operational safe yield of the basin is 224,300 AFY.

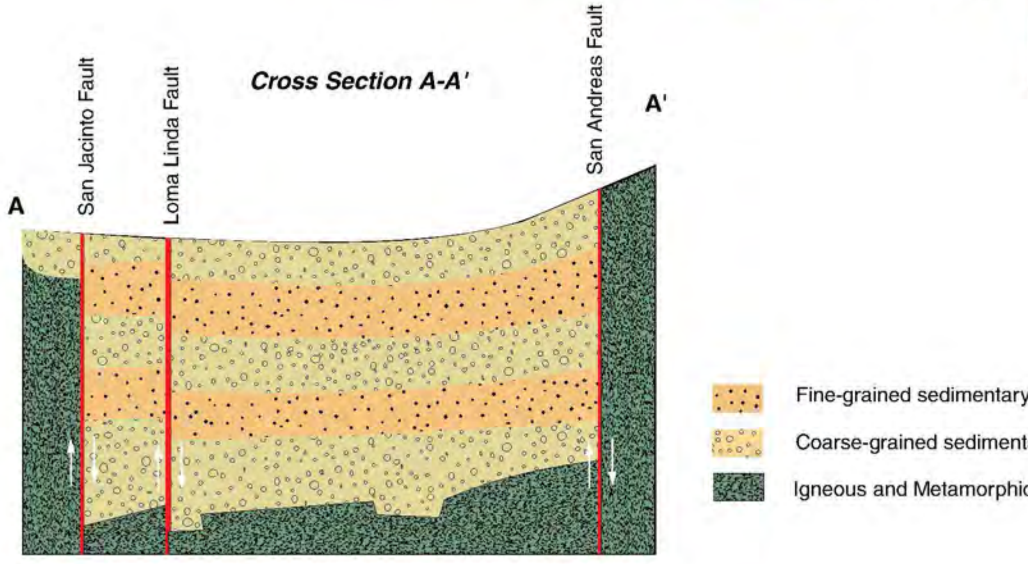
Basin Sediments

The basin is a sediment-filled structural trough between the San Andreas and San Jacinto faults in the upper part of the Santa Ana River Watershed near the base of the San Bernardino Mountains. Sediments generally consist of unconsolidated alluvial fan deposits derived from the surrounding mountains and hills. These deposits interfinger with river-channel deposits, primarily from the Santa Ana River, and with freshwater marsh deposits associated with groundwater discharge near the San Jacinto fault. Younger alluvium consists of boulders, gravel, sand, silt, and clay. The depth to the base of the younger alluvium ranges from 70 to 110 feet. Older alluvium consists of gravel, sand, silt, and clay, is fractured by numerous faults, and constitutes the principal aquifer of the area. A bedrock complex of igneous and metamorphic rocks underlies valley fill sediment.

Conjunctive Use Potential

The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 6,000 AFY. The basin is full so there is currently no storage space available for dry year storage.





12. San Jacinto Watershed Basins

Location
The basins of the San Jacinto Watershed are located in western Riverside County and consist of the following subbasins:

- Lakeview
- Perris North and South
- Winchester
- San Jacinto - Lower Pressure
- Menifee
- East Valley or East San Jacinto Groundwater Basin Area
- San Jacinto - Canyon
- San Jacinto - Intake and Upper Pressure
- Hemet

Basin Management
The Lakeview, Perris North, Perris South, Winchester, San Jacinto Lower Pressure, and Menifee subbasins are managed under the West San Jacinto Groundwater Management Plan (AB3030) adopted in June 1995. The Eastern Municipal Water District (EMWD) is the basin manager under the Plan. The basins are not adjudicated.

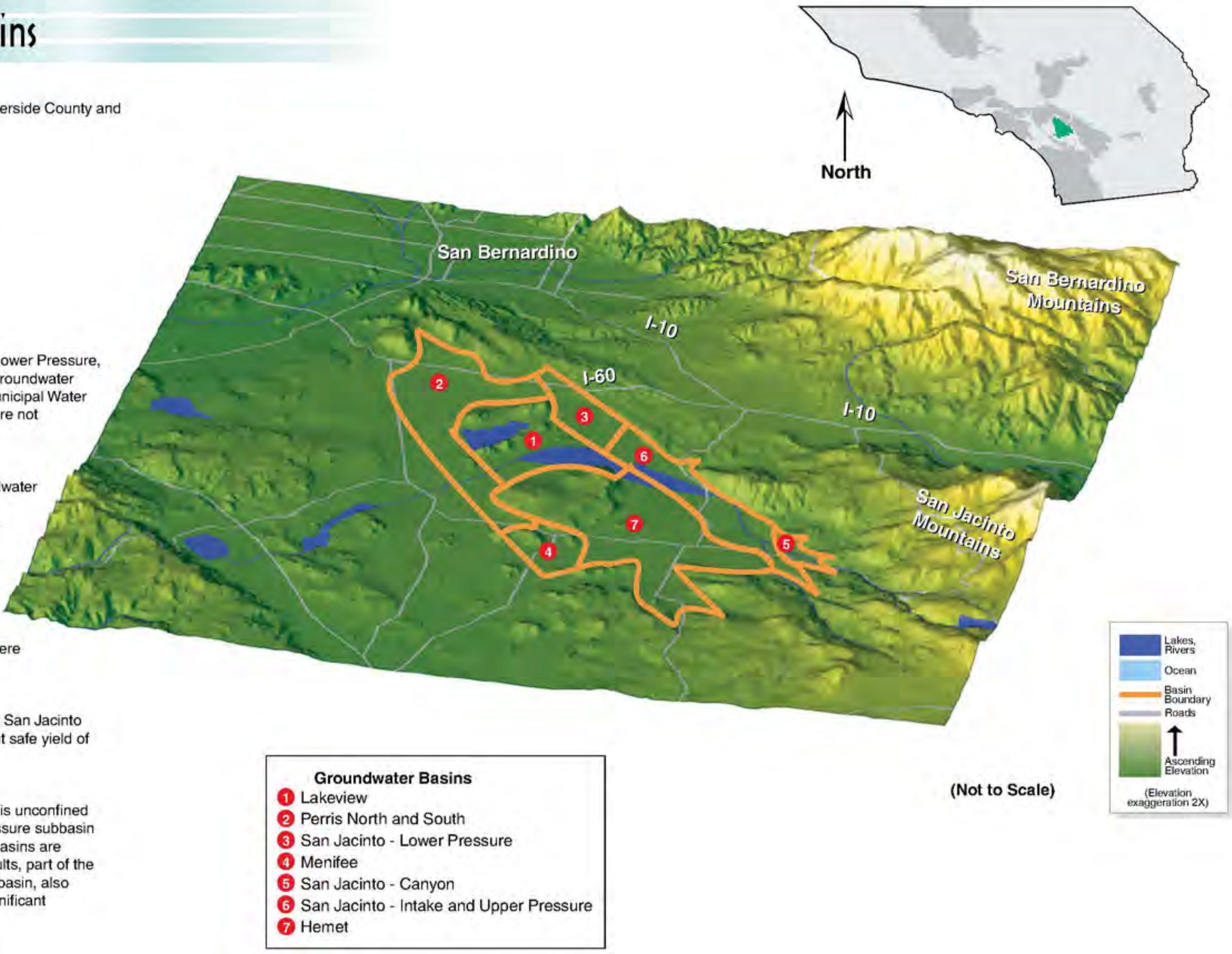
The San Jacinto Canyon, Intake and Upper Pressure, and Hemet subbasins are known as the East Valley or East San Jacinto Groundwater Basin Area. EMWD, local agencies/cities, and private groundwater producers are working to develop a groundwater management plan. The basins are not adjudicated.

Available Storage
The freshwater storage capacity of the basins of the West San Jacinto Groundwater Management Plan Area is 5,254,500 AF, and there are 726,000 AF of available storage. The freshwater storage of the basins of the East Valley Area is 5,080,000 AF and there are 558,000 AF of available storage.

Present Operational Safe Yield
The present operational safe yield of the nine subbasins in the West San Jacinto Groundwater Management Plan Area is 22,000 AFY and the present safe yield of the three subbasins in the East Valley Area is 60,000 AFY.

Basin Sediments
The groundwater aquifers consist of alluvial deposits. Groundwater is unconfined with the exception of the groundwater in the San Jacinto Lower Pressure subbasin which is a confined aquifer. The San Jacinto Upper and Lower subbasins are defined by the graben formed by the Casa Loma and Claremont Faults, part of the San Jacinto Fault Zone. The fault zone, in the northeast part of the basin, also contains the Park Hill, Bautista, and other named faults, and is a significant feature in the Basin.

Conjunctive Use Potential
The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 3,000 AFY. Additionally, the survey indicated the potential to store up to 1,284,000 AF of water for use in dry years and a potential increase in basin operational yield of 10,000 AFY.



Groundwater Basins
1. Lakeview
2. Perris North and South
3. San Jacinto - Lower Pressure
4. Menifee
5. San Jacinto - Canyon
6. San Jacinto - Intake and Upper Pressure
7. Hemet

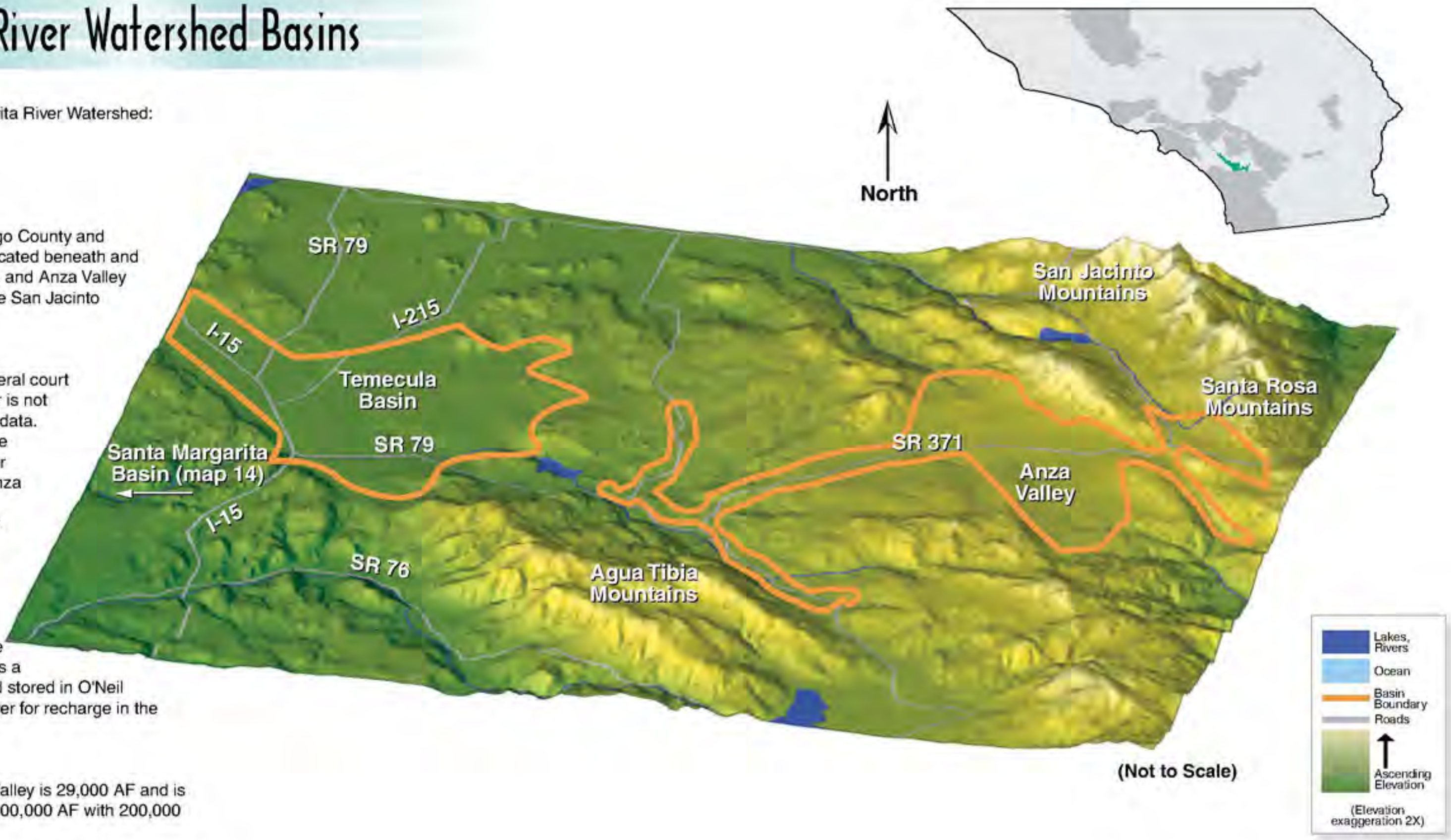
13. Upper Santa Margarita River Watershed Basins

Location
There are three major groundwater basins of the Santa Margarita River Watershed:

- Santa Margarita Basin (location shown on map 14 due to its location in San Diego County)
- Temecula Basin
- Anza Valley

The Santa Margarita Basin is located in northwestern San Diego County and underlies Camp Pendleton (See map 14). Temecula Basin is located beneath and around the City of Temecula, in south-central Riverside County, and Anza Valley is located to the east along Highway 371 and to the south of the San Jacinto Mountains and to the west of the Santa Rosa Mountains.

Basin Management
The Santa Margarita River Watershed is adjudicated under federal court jurisdiction. The Santa Margarita River Watershed Watermaster is not charged with basin management but does collect and manage data. The Santa Margarita Basin is managed by Camp Pendleton; the Temecula Basin is largely managed by Rancho California Water District and to a lesser extent by Murietta Water District; and Anza Valley is not managed. Currently, the watershed has three ongoing conjunctive use projects, two of which are operated by Rancho California Water District and one by Camp Pendleton. Rancho California Water District imports water for recharge into spreading basins and extracts the water using wells. The District also owns Vail Lake on Temecula Creek. During wet years, water is impounded behind Vail Lake and later released, recharged in spreading basins and the creek bottom, and extracted by wells. Camp Pendleton operates a seasonal conjunctive use project whereby water is diverted and stored in O'Neil Lake during the wet months and later released back into the river for recharge in the fall.



Available Storage
The freshwater storage capacity of the Santa Margarita River Valley is 29,000 AF and is currently full. The storage capacity of the Temecula Basin is 2,000,000 AF with 200,000 AF of available storage.

Present Operational Safe Yield
The present operational safe yields of the Santa Margarita Basin, Temecula Basin, and Anza Valley are 5,600 AFY, 37,700 AFY and 12,000 AFY respectively.

Basin Sediments
Groundwater generally occurs in three aquifer zones:

- Younger to older alluvium (Top Zone)
- Pauba Aquifer (Middle Zone)
- Temecula Arkose (Bottom Zone)

All three zones are present in the Temecula Basin, whereas younger alluvium dominates the Santa Margarita Basin and both older and younger alluvium comprise the Anza Valley.

Conjunctive Use Potential
The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 10,000 AFY. Additionally, the survey indicated the potential to store up to 200,000 AF of water for use in dry years and a potential increase in basin operational yield of 10,000 AFY.

14. San Diego County Basins

Location
San Diego County overlies numerous groundwater basins. Seven of the basins, each with a total storage capacity greater than 10,000 AF, are listed below and shown on the map.

- Santa Margarita River Basin
- Warner Basin
- San Pasqual Basin
- Santa Maria Basin
- Santee/El Monte Basin
- Mission Valley Basin
- San Diego Formation Aquifer
- San Luis Rey River Basin

Basin Management
Water rights court decisions have been rendered within the Santa Margarita Basin, upper San Luis Rey River, lower Tijuana River Valley, and the San Diego River watersheds. Other watersheds in the county remain non-adjudicated; however, a number of agencies have long-standing surface water rights.

Available Storage
The combined fresh water storage capacity within the alluvial aquifers is estimated to exceed 700,000 acre-feet (AF). In addition to the shallow alluvial aquifers, a deeper aquifer exists in the southwest corner of the county, termed the San Diego Formation Aquifer. The San Diego Formation aquifer has been estimated to have a storage capacity in excess of 960,000 AF. Though active management of both groundwater pumping and groundwater quality, storage in these basins can be utilized for conjunctive use.

Present Operational Safe Yield
The present operational safe yield of these basins is approximately 60,000 AF.

Basin Sediments
The principal aquifer materials are alluvium, semi-consolidated sediment, and to a lesser degree, consolidated sediment, residuum, and fractured crystalline rock. Unconsolidated deposits of alluvium and residuum are typically found near the surface in major river and stream valleys.

Conjunctive Use Potential
The results of AGWA's survey indicate the potential to store up to 270,700 AF of water for use in dry years and a potential increase in basin operational yield of 41,500 AFY.

Groundwater Basins

1. Santa Margarita River Basin
2. Warner Basin
3. San Pasqual Basin
4. Santa Maria Basin
5. Santee/El Monte Basin
6. Mission Valley Basin
7. San Diego Formation Aquifer
8. San Dieguito River Basin
9. Lower Tijuana River Valley Basin
10. Sweetwater River
11. San Luis Rey River Basin

15. Mojave River Basins

Location
The Mojave Basin, traversed by the Mojave River, extends from the north side of the San Bernardino Mountains to the north and east through the cities of Victorville and Barstow. The basin is comprised of the following subbasins:

- Alto
- Centro
- Baja
- Este

Basin Management
The Mojave Water Agency (MWA) oversees groundwater production and recharge within the basin. The basin is adjudicated, with the goals of balancing pumped groundwater with imported water and natural recharge, in addition to returning groundwater levels to those of the 1930s. Although MWA does not currently restrict groundwater pumping, well owners must pay an assessment for groundwater pumped in excess of an annual allowance determined by MWA. Alternatively, a well owner may acquire unused pumping allowances from well owners located in the same groundwater subbasin. Ultimately, the assessment value will be equal to the cost of delivery and replacement of groundwater pumped in excess of the well owner's allowance.

Two pipelines bring imported surface water to the Mojave Basin. MWA currently oversees the operation of four groundwater recharge facilities that draw water from these pipelines. The recharge facilities and associated theoretical maximum recharge rates are listed below.

In addition to the above recharge facilities, discharges from Lake Silverwood occasionally provide recharge to the west fork of the Mojave River. Historic discharge rates vary from 2,000 to 25,000 AFY.

(Not to Scale)

Available Storage
Water levels in the Mojave Basin have been declining since the 1930s. As a result, the amount of available storage for conjunctive use has increased substantially. Since one of the goals of the basin adjudication is to return groundwater levels to pre-development conditions, the available storage may decrease in the future. Presently, the available storage of the basin is estimated as follows:

Subbasin	Available Storage
Alto	1,041,500 AF
Centro	217,700 AF
Baja	415,000 AF
Este	115,900 AF

Present Operational Safe Yield
The present operational safe yield of the Basin is summarized in the table below:

Subbasin	Present Operational Safe Yield
Alto	69,860 AFY
Centro	33,380 AFY
Baja	20,680 AFY
Este	7,160 AFY

Basin Sediments
The Mojave Basin is comprised of sand, gravel, and occasional clay deposits created by the Mojave River and surrounding streams. Impermeable metamorphic and igneous rocks that comprise the San Bernardino Mountains limit the southern extent of the basin. Intermittent streams generated by winter and summer precipitation supply natural groundwater recharge to this sedimentary basin.

Conjunctive Use Potential
The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 46,000 AFY. Additionally, the survey indicated the potential to store up to 1,790,100 AF of water for use in dry years and a potential increase in basin operational yield of 24,000 AFY.

16. Hayfield Basin

Location
The Hayfield Groundwater Basin is located in Riverside County, east of the Coachella Valley, west of Chuckwalla Valley, and south of the Eagle Mountains. Surface area of the basin is approximately 37 square miles (23,900 acres).

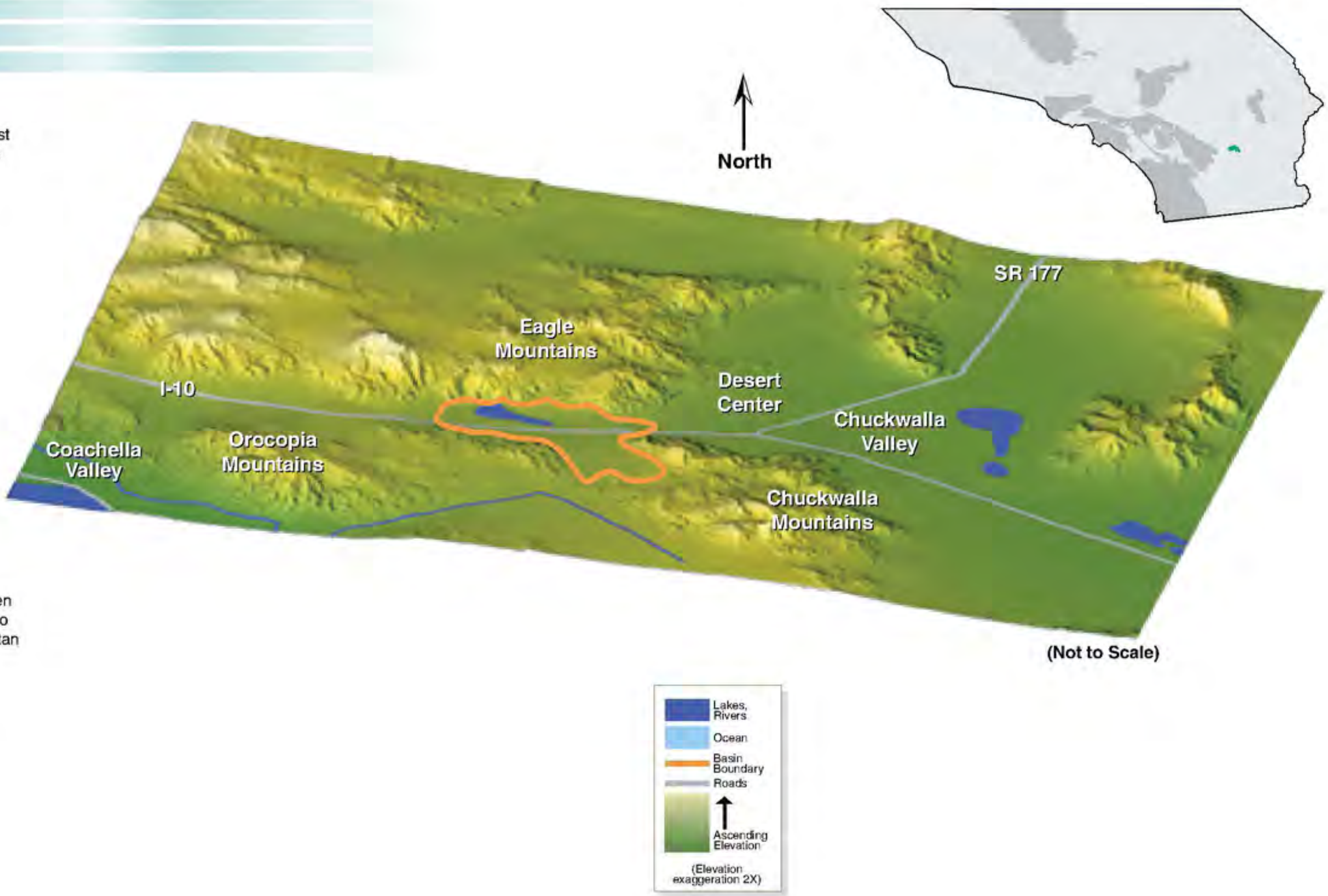
Basin Management
The Basin is neither adjudicated nor formally managed.

Available Storage
The total estimated storage capacity of the basin is 2,800,000 acre-feet (AF), with about 2,000,000 AF of native water in storage.

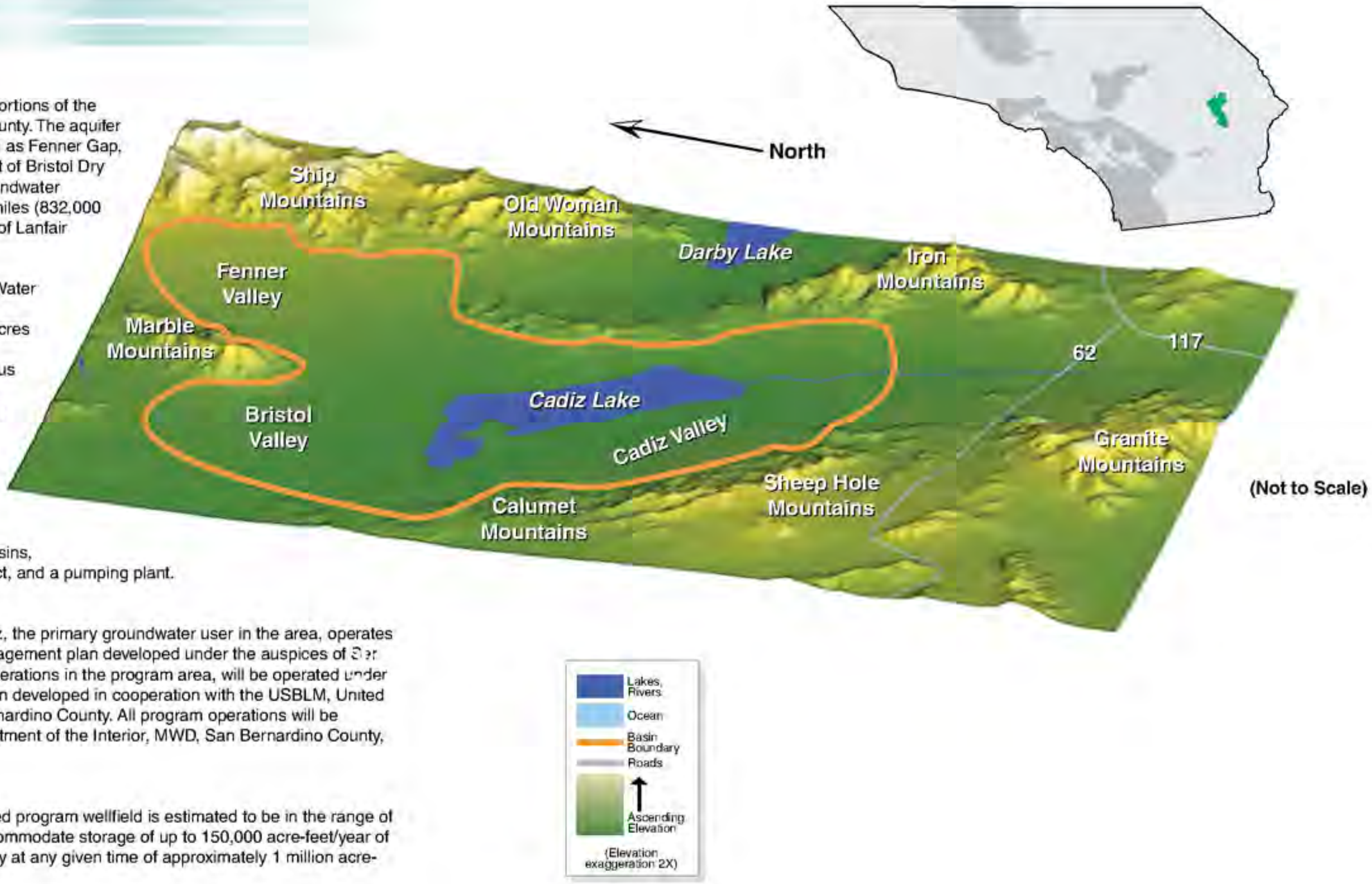
Present Operational Safe Yield
The present operational safe yield is undefined. Future operational yield may be 150,000 acre-feet per year (AFY) in a drought year.

Basin Sediments
Basin sediments consist of alluvial deposits with interbeds of sand, gravel, silt, and clay. Groundwater is unconfined.

Conjunctive Use Potential
The results of AGWA's survey indicate the potential to store between 500,000 and 800,000 AF of water for use in dry years. A program to utilize this storage potential is currently being planned by Metropolitan Water District of Southern California.



17. Cadiz Valley Basin



Location

The Cadiz Groundwater Storage and Dry-Year Supply Program is located in portions of the Cadiz and Fenner Valleys in the Mojave Desert of eastern San Bernardino County. The aquifer system to be utilized by this conjunctive use program underlies an area known as Fenner Gap, located between the Marble and Ship mountains, approximately ten miles east of Bristol Dry Lake and ten miles north of Cadiz Dry Lake. The watershed that supplies groundwater recharge to the program area covers an area of approximately 1,300 square miles (832,000 acres), and includes the Fenner Valley, Orange Blossom Wash, and a portion of Lanfair Valley.

This conjunctive use program is a cooperative venture between Metropolitan Water District of Southern California (MWD) and Cadiz Inc. (Cadiz) a publicly traded agricultural and water development company. Cadiz owns more than 27,000 acres in the program area and has developed approximately 1,600 acres of citrus orchards, table grape vineyards, and specialty row-crops utilizing the indigenous groundwater. MWD and Cadiz have conducted extensive engineering and hydrological studies in the program area, including an 8-month pilot spreading basin test to measure site-specific infiltration rates. Over the 50-year term of the proposed program, MWD will store water imported from its Colorado River Aqueduct during periods of excess supply. This stored water and indigenous groundwater will be conveyed back to the Colorado River Aqueduct as needed. In cooperation with the United States Bureau of Land Management (USBLM), MWD has completed a Draft EIR/EIS and a supplement to the Draft EIR/EIS. Program facilities will include spreading basins, extraction wells, a 35-mile conveyance pipeline to the Colorado River Aqueduct, and a pumping plant.

Basin Management

The aquifer system in the vicinity of the program area is not adjudicated. Cadiz, the primary groundwater user in the area, operates its agricultural wellfield in compliance with a groundwater monitoring and management plan developed under the auspices of San Bernardino County. The conjunctive use program, and all future agricultural operations in the program area, will be operated under a comprehensive groundwater monitoring and management plan that has been developed in cooperation with the USBLM, United States Geological Society (USGS), National Park Service (NPS) and San Bernardino County. All program operations will be overseen by a Basin Management Group to be represented by the U.S. Department of the Interior, MWD, San Bernardino County, and Cadiz.

Available Storage

The volume of indigenous groundwater in storage in the vicinity of the proposed program wellfield is estimated to be in the range of 3.65 to 6.69 million acre-feet. The conjunctive use program is designed to accommodate storage of up to 150,000 acre-feet/year of water imported from the Colorado River Aqueduct, with a total storage capacity at any given time of approximately 1 million acre-feet.

Present Operational Safe Yield

Estimates of safe yield will be refined as more data become available during operation of the conjunctive use program. Storage and extraction of imported water and transfers of indigenous groundwater will be authorized by the Basin Management Group only to the extent these operations will not adversely impact critical environmental resources in and surrounding the program area.

Basin Sediments

The aquifer system underlying the conjunctive use program area is composed of alluvial sediments of mid- to late-Tertiary and Quaternary age. These sediments are derived from Precambrian basement rock, Paleozoic sediments, and Tertiary volcanic rocks that are exposed in the mountain ranges in and surrounding the watershed. Geophysical surveys indicate that this alluvial fill locally exceeds 3,500 feet in thickness beneath portions of the program area.

Conjunctive Use Potential

The results of AGWA's survey indicate the potential to store up to 1,000,000 AF of water for use in dry years.

18. Coachella Valley Basin

Location
The Coachella Valley is located approximately 107 miles east of Los Angeles. The vast majority of the valley lies within Riverside County. Coachella Valley is bounded on the north by the San Bernardino and Little San Bernardino Mountains, on the east by Mecca Hills, on the south by the Salton Sea and Santa Rosa Mountains, and on the west by the San Jacinto Mountains. The San Andreas, Banning and Mission Creek faults separate the valley into three sub-basins: the Indio, Mission Creek and Desert Hot Springs sub-basins. Each of these faults are effective barriers to groundwater flow. The Whitewater River drains the valley to the Salton Sea, which has no outlet.

Basin Management
The Coachella Valley Stormwater District was formed in 1915 followed by formation of the Coachella Valley Water District (CVWD) in 1918. These districts merged in 1937. In 1918, a contract was awarded to construct spreading facilities northwest of Palm Springs to recharge stormwater from the Whitewater River.

The Coachella Valley is heavily dependent on groundwater and imported water to meet water demands. In response to declining groundwater levels, CVWD signed a contract with the federal government to construct the Coachella Branch of the All-American Canal, which was completed in 1949. Canal water is delivered to farms and golf courses for irrigation.

In 1963, CVWD and Desert Water Agency (DWA) signed contracts with State of California for 61,200 acre-feet per year (AFY) of entitlements to State Water Project (SWP) water. CVWD and DWA exchange their SWP entitlements with the Metropolitan Water District of Southern California (MWD) for Colorado River water. This exchange water is recharged at the Whitewater Spreading Facility located north of Palm Springs. CVWD, DWA and MWD signed an advanced delivery agreement in 1984 that allows Metropolitan to store surplus Colorado River Water in the valley. CVWD and DWA have also purchased unused SWP water when it is available. Since 1973, over 1.7 million acre-feet (AF) imported water has been recharged at the whitewater facility. MWD currently has about 290,000 AF of water stored in the valley.

CVWD and DWA also have active water recycling and water conservation programs. Currently, about 8,000 AFY of recycled water is used for park and golf course irrigation. Water conservation programs focus on public information, school education, and use of water-efficient irrigation systems and landscaping techniques.

CVWD is completing a water management plan to resolve the on-going groundwater overdraft. This plan includes increased water conservation, water recycling, delivery of Colorado River water to additional farms, golf courses and municipal users and groundwater recharge. CVWD has conducted a pilot recharge test program at Dike No. 4 located south of La Quinta. If successful, a facility capable of recharging 30,000 to 60,000 AFY could be constructed at this location. Additional recharge facilities are also being evaluated. Additional imported water is expected to come from SWP entitlement transfers and quantification of California's Colorado River allocation.

The groundwater basin is not adjudicated. However, CVWD and DWA collect replenishment assessments from groundwater producers in the northwestern portion of the Indio sub-basin.

Available Storage
The freshwater storage capacity of the valley is approximately 37 million AF. Of this amount, the Indio sub-basin has a capacity of about 30 million AF. Available storage capacity in the Indo sub-basin is about 4 million AF.

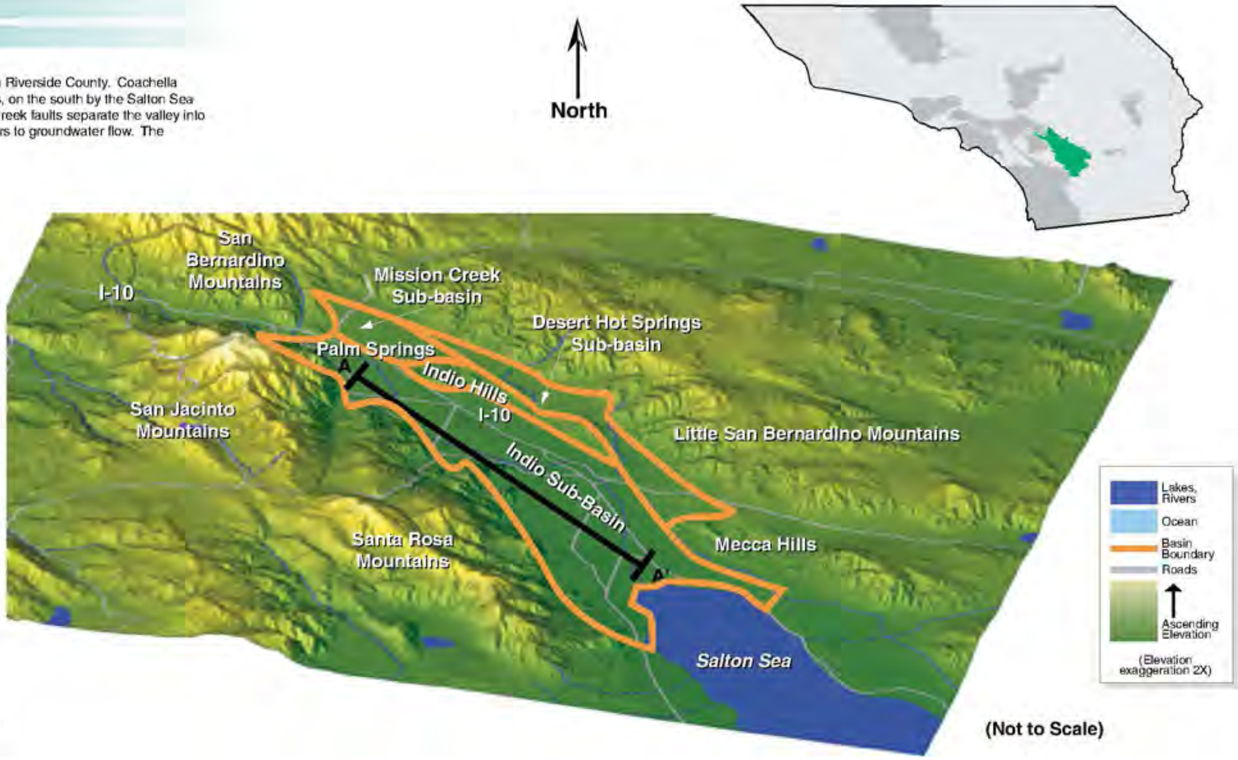
Present Operational Safe Yield
The present operational safe yield of the valley is estimated to be 220-250,000 AFY.

Basin Materials
The conceptual hydrogeological model of the Coachella Valley includes four zones :

- The Semi-Perched aquifer and intervening retarding layers (correlated with Recent lake deposits and alluvium)
- The Upper aquifer (correlative with Upper Pleistocene Alluvium)
- An aquitard
- The Lower aquifer (correlative with the Pleistocene Ocotillo conglomerate)

South of Indio, all four hydrostratigraphic units are clearly present in the center of the Indio sub-basin. At the margins of the sub-basin, the proportion of clay decreases thereby allowing for continuity between the Upper and Lower aquifers. Because of the thick clay aquitard separating the Upper and Lower aquifers, groundwater recharge is limited to the margins of the Valley. North of Indio, the aquitard is discontinuous or absent throughout much of the sub-basin. Therefore, this area provides greater opportunity for direct groundwater recharge.

Conjunctive Use Potential
The results of AGWA's survey indicate existing conjunctive use programs have increased the basin operational yield by 50,000 AFY. Additionally, the survey indicated the potential to store up to 4,000,000 AF of water for use in dry years and a potential increase in basin operational yield of 80,000 AFY.



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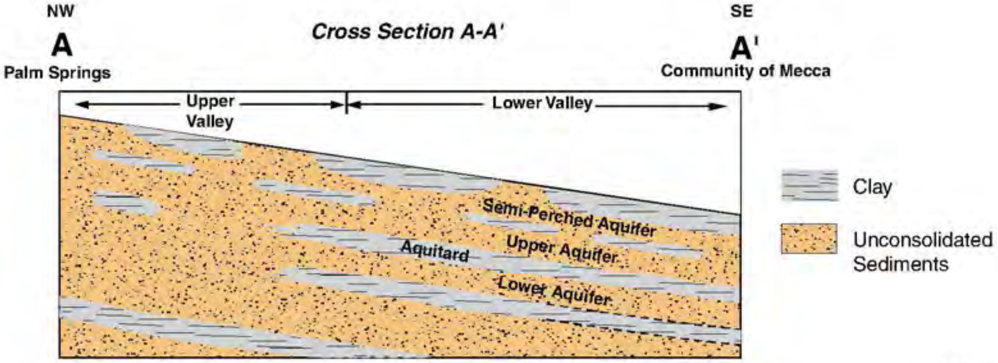


Responses to AGWA's Questionnaire

Compiling the survey responses, AGWA has estimated the storage available for conjunctive use in some 85 groundwater basins of Southern California. For the purposes of this guide, conjunctive use potential includes both dry-year or longer-term storage and shorter-term programs such as annual put and take or seasonal storage operations. By using the groundwater aquifer for storage, surplus water available in wet years is used to meet future dry-year demand as shown in Figure 6. Stored water can also be used to increase the basin yield.

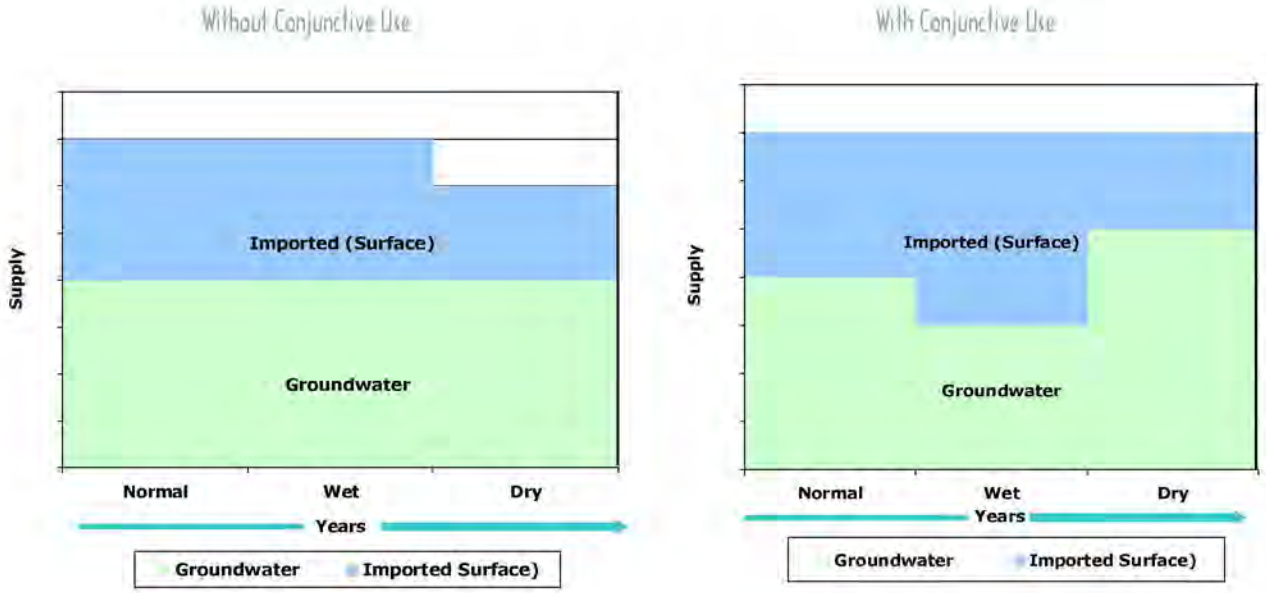
Many basins already have conjunctive use programs in place. Existing conjunctive use programs currently provide an estimated 2.5 MAF of water per year as shown on Figure 7.

However, these existing programs represent only a small fraction of the conjunctive use potential identified by the AGWA survey throughout Southern California. Figure 8 illustrates the dry-year storage available by basin, which totals 21.5 million acre-feet (MAF) for all basins combined. The short-term storage, or future increase in operational yield, totals 1.3 MAF per year as shown on Figure 9.

Summary

Over the centuries, people have devised ways to regulate the flows of surface water systems by impounding rivers and streams behind dams to capture and retain water for use in dry periods and releasing controlled amounts in order to accommodate downstream demands. However, substantial amounts of water remain unused, particularly in wet years, due to inherent limitations in these surface water systems. Major improvements in these systems could be achieved by coordinating the use of both surface water and groundwater. This coordination involves diverting and/or conveying water for storage underground

Figure 6
Conjunctive Use for Dry Year Storage



Without Conjunctive Use

With Conjunctive Use

Figure 7

Existing Increase in Basin Yield from Conjunctive Use Programs

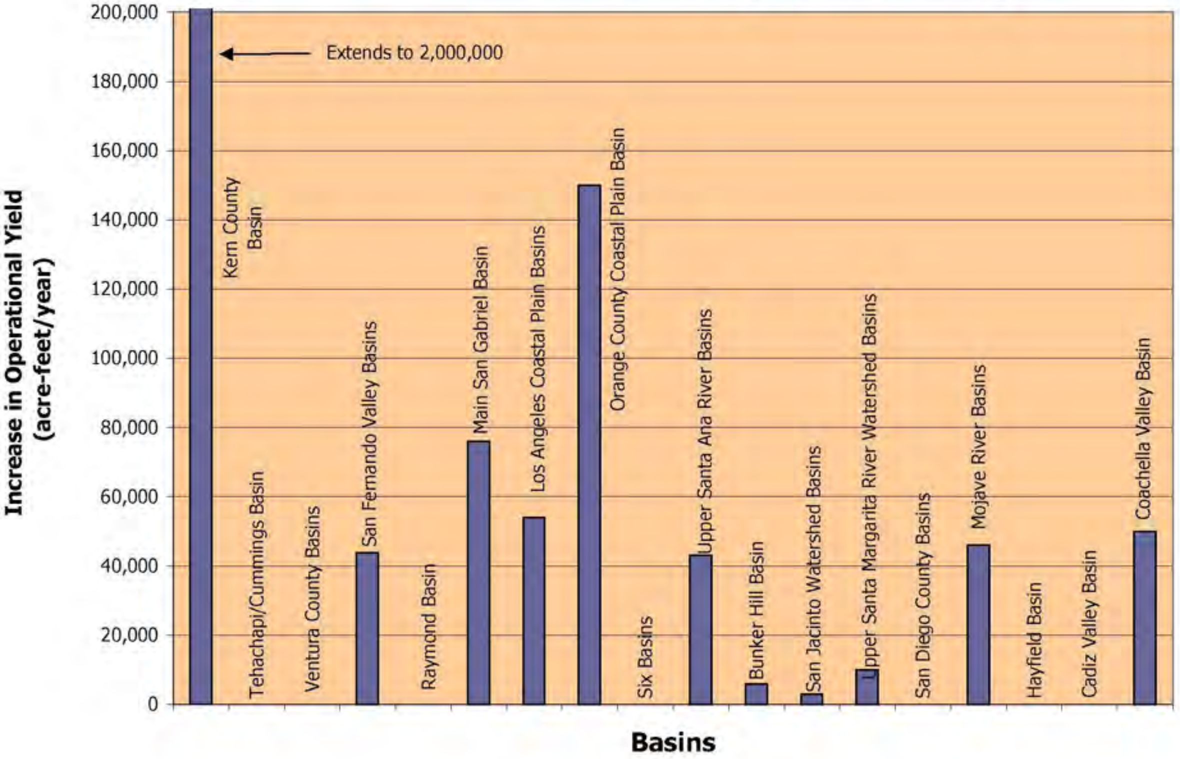
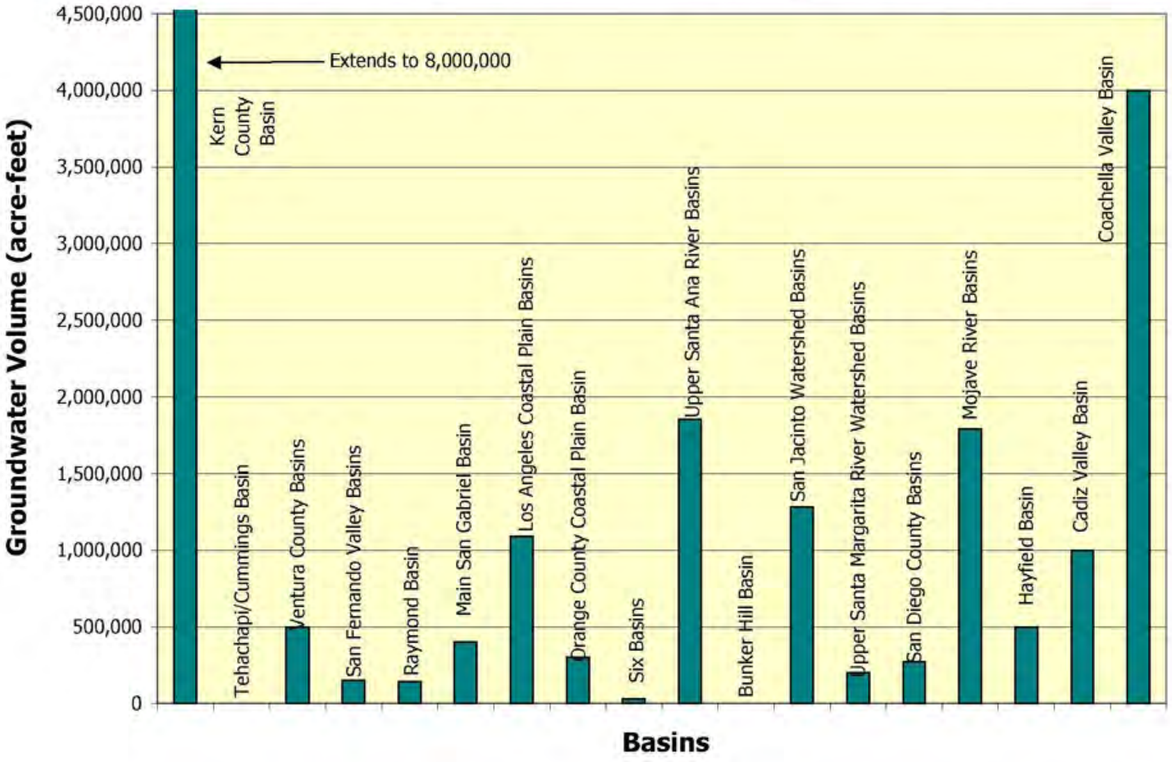


Figure 8

Potential Dry Year or Long Term Groundwater Storage From Conjunctive Use



when surface water is in abundance to provide reliability during drought periods. During droughts, the stored water can be pumped from underground and used to meet present demands. Stored underground water may also be used to meet "peak" demand, so that surface water storage and distribution systems can be built to an average-demand capacity rather than a peak load capacity. Such "conjunctive use" of groundwater and surface or imported supplies improves the overall reliability, efficiency and value of our water system.

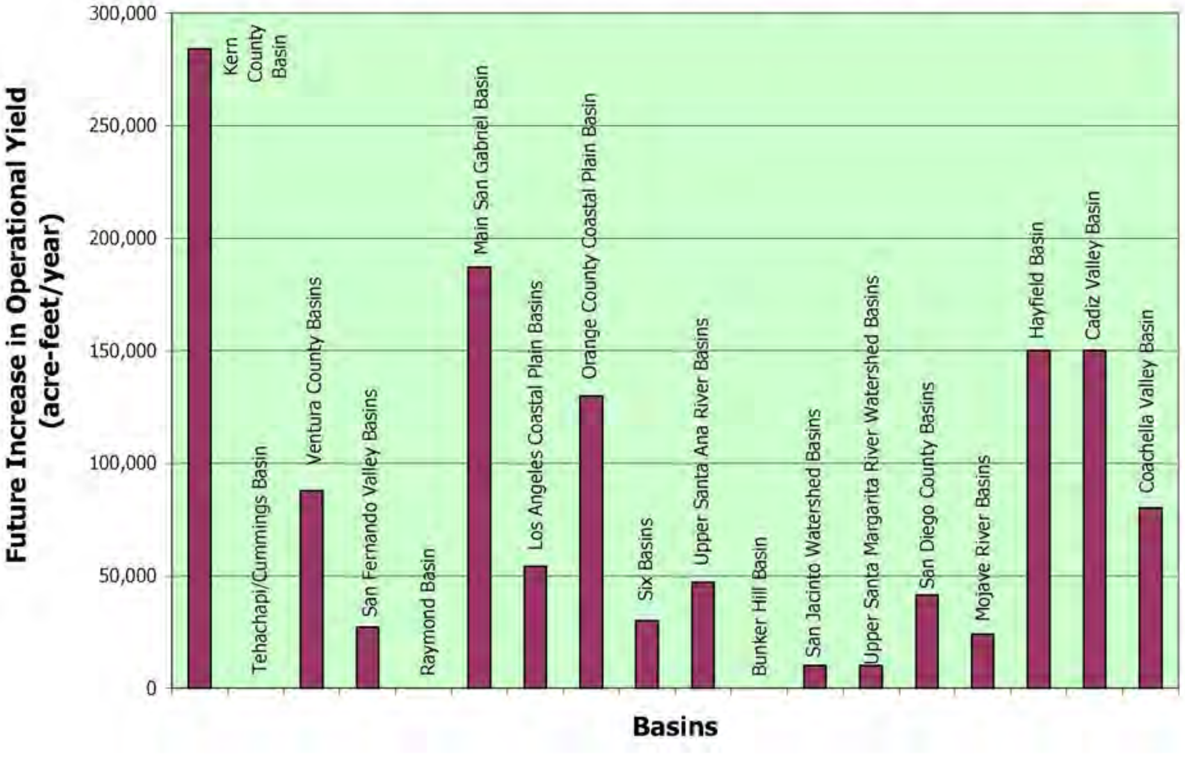
Through the data collected in the preparation of this guide, AGWA has documented the following:

- Conjunctive use is a well-proven method to increase our ability to meet California's increasing water demand.
- Conjunctive use improves water supply reliability.
- The need for additional, environmentally controversial, surface water reservoirs may be reduced by conjunctive use programs.
- Assuming resolution of institutional, water quality, and other issues, over 21.5 million acre-feet of additional water can be stored and used in Southern California groundwater basins.

Conjunctive use is becoming a key part of California's overall water management strategy for allocating an increasingly scarce resource among a steadily growing population. This guide demonstrates that in Southern California basins alone, approximately 21.5 million acre-feet of additional conjunctive use potential is available, enough to fill Diamond Valley Lake, Southern California's largest surface water reservoir, 26 times over. This stored water could be used during times of drought or natural disaster when surface water supplies are reduced or not available.

Figure 9

Potential Annual Operational Yield Increase from Conjunctive Use



Glossary

acre-foot—325,851 gallons, or enough water to cover an acre of land 1 foot deep. An acre-foot can supply the annual needs of between one and two average California households.

artificial recharge— the purposeful addition of surface water to a groundwater basin by human activity such as percolation ponds or injection wells.

aquifer—a geologic formation that stores, transmits, and yields significant quantities of water to wells or springs.

available storage—the current amount of space in a groundwater basin that can be used for water storage.

confined aquifer—an aquifer that is bound above and below by impermeable layers of soil or rock.

conjunctive-use potential— For the purposes of this guide, conjunctive use potential includes both dry-year or longer-term storage and shorter-term programs such as annual put and take or seasonal storage operations.

dry year—a year with below-average precipitation.

evapotranspiration—the combined losses of water through the processes of evaporation and uptake and use by vegetation (transpiration).

extraction— the process of withdrawing groundwater from storage by pumping or other controlled means.

groundwater—water stored underground in pore spaces within rocks and other alluvial materials and in gaps between fractured hard rock.

hydrologic cycle— the natural recycling process powered by the sun that causes water to evaporate into the atmosphere, condense, and return to the earth as precipitation.

impermeable—having a texture that does not permit water to move through quickly.

in-lieu recharge—an indirect method of recharge caused by reducing the amount of water pumped from the aquifer.

operational yield—The augmentation of safe yield by the use of engineering controls (i.e. recharge basins, injection wells) such that more water is made available to meet an increased demand.

overdraft— intentional or inadvertent withdrawal of water from an aquifer in excess of the amount of water that recharges the basin over a period of years.

percolation—the movement of water through small openings within a porous material.

permeability—the capability of soil or rock to transmit water.

recharge—flow to groundwater storage from precipitation, irrigation, spreading basins and other sources of water.

safe yield—the amount of water that can be pumped each year without causing a continual reduction of water in storage (overdraft). The safe yield is dependent upon the average amount of water that can be stored in and used from the groundwater reservoir over a period of normal water supply under a given set of conditions.

saturated zone— the area below the water table in which the soil is completely saturated with groundwater.

seasonal (short-term) storage—For the purposes of this guide, the short term or seasonal storage quantity represents the amount of water that can be put in and taken out of storage on an annual basis.

salt water intrusion—the movement of salty water into fresh water aquifers. When groundwater pumps draw up fresh water from the aquifer, salty water can flow into the aquifer and make it unuseable.

subsidence—lowering or sinking of the land surface due to a number of factors, of which groundwater extraction is one.

surface water—water that remains on the earth's surface in rivers, streams, lakes, reservoirs or oceans.

unsaturated zone—the subsurface zone, usually starting at the land surface and ending at the water table, that includes both water and air in spaces between rocks.

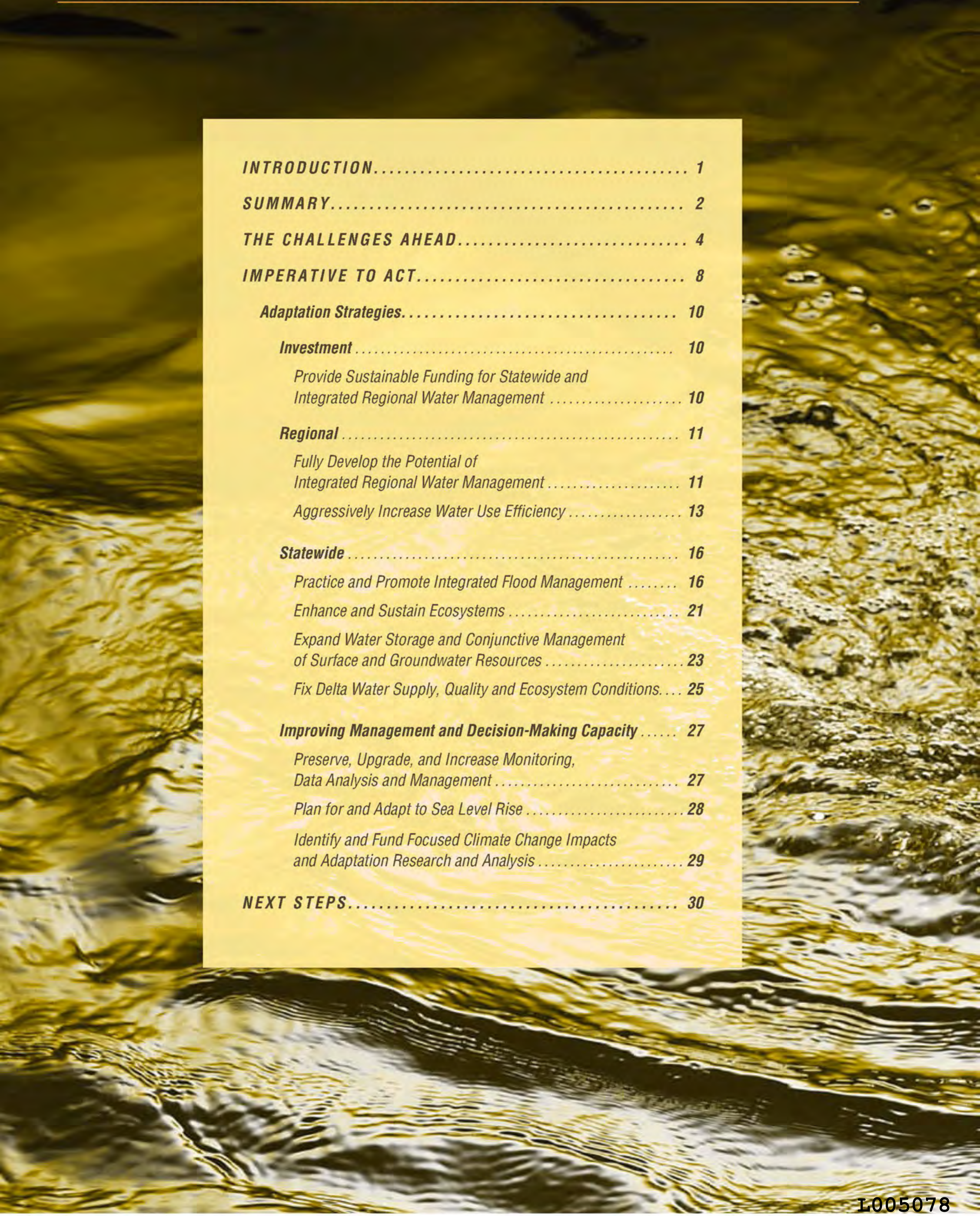
Contact List of Basin Managers

Map	Basin Name	Management Agency	Contact Person	Phone Number
1	Kern County Basin	Kern County Water Agency	Rick Iger	661-634-1469
2	Tehachapi/Cummings Basin	Tehachapi-Cummings County Water District	John Otto	661-822-5504
3	Ventura County Basins	United Water Conservation District	Dana Wisehart	805-525-4431
4	San Fernando Valley Basins	Watermaster - Upper Los Angeles River Area	Melvin Blevins	213-367-1020
5	Raymond Basin	Raymond Basin Management Board	Ronald Palmer	818-790-4036
6	Main San Gabriel Basin	Main San Gabriel Basin Watermaster	Carol Williams	626-815-1300
7	Los Angeles Coastal Plain Basins	Water Replenishment District of Southern California	Robb Whitaker	562-921-5521
8	Orange County Coastal Plain Basin	Orange County Water District	William Mills	714-378-3200
9	Six Basins	Three Valleys Municipal Water District	Mario Garcia	909-621-5568
10	Upper Santa Ana River Basins	Chino Basin Watermaster	Robert Neufeld	909-484-3888
11	Bunker Hill Basin	San Bernardino Valley Water Conservation District	Tom Crowley	909-793-2503
12	San Jacinto Watershed Basins	Eastern Municipal Water District	Behrooz Mortazavi	909-928-3777
13	Upper Santa Margarita River Watershed Basins	Santa Margarita River Watermaster	James Jenks	760-728-1028
14	San Diego County Basins	San Diego County Water Authority	Daniel Diehr	619-682-4100
15	Mojave River Basins	Mojave Water Agency	Mark Lund	760-240-9201
16	Hayfield Basin	Metropolitan Water District	Steve Arakawa	213-217-6052
17	Cadiz Valley Basin	Metropolitan Water District	Steve Arakawa	213-217-6052
18	Coachella Valley Basin	Coachella Valley Water District	Tom Levy	760-398-2651

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
OCTOBER 2008

MANAGING AN UNCERTAIN FUTURE

Climate Change Adaptation Strategies for California's Water



INTRODUCTION

For California water managers, the future is now. Climate change is already having a profound impact on water resources as evidenced by changes in snowpack, river flows and sea levels.

The Department of Water Resources (DWR) will continue to play a leadership role in adapting to these changes. DWR is already engaged in a number of efforts designed to improve California's ability to cope with a changing climate. However, more must be done. This report recommends a series of adaptation strategies for state and local water managers to improve their capacity to handle change. Many of the strategies will also help adapt our water resources to accommodate non-climate demands including a growing population, ecosystem restoration and greater flood protection.

Adapt or perish,
now as ever, is nature's
inexorable imperative.
- H. G. Wells

Several of the recommendations in this report are ready for immediate adoption, while others need additional public deliberation and development. Some can be implemented using existing resources and authority, while the majority will require new resources, sustained financial investment and significant collaborative effort.

Many of California's most important water resource investments remain dependent on bond funding approved by voters. As a result, they are well-funded in some years, but underfunded in most. This history of uneven and irregular investment has delayed progress in areas that have the potential to yield substantial gains over short periods of time.

DWR presents this report as part of the process of updating the California Water Plan, and as part of the California Resources Agency's draft statewide Climate Adaptation Plan. Overall, this report urges a new approach to managing California's water and other natural resources in the face of a changing climate.

Lester A. Snow
Director

SUMMARY

Climate change is already affecting California's water resources. Bold steps must be taken to reduce greenhouse gas emissions. However, even if emissions ended today, the accumulation of existing greenhouse gases will continue to impact climate for years to come. Warmer temperatures, altered patterns of precipitation and runoff, and rising sea levels are increasingly compromising the ability to effectively manage water supplies, floods and other natural resources. Adapting California's water management systems in response to climate change presents one of the most significant challenges of this century.

Chinook salmon

What we know:

- Historic hydrologic patterns can no longer be solely relied upon to forecast the water future;
- Precipitation and runoff patterns are changing, increasing the uncertainty for water supply and quality, flood management, and ecosystem functions;
- Significant and ongoing investments must be made in monitoring, researching, and understanding the connection between a changing climate, water resources and the environment;
- Extreme climatic events will become more frequent, necessitating improvements in flood protection, drought preparedness and emergency response;
- Water and wastewater managers and customers – businesses, institutions, farms, and individuals – can play a key role in water and energy efficiency, the reduction of greenhouse gas emissions, and the stewardship of water and other natural resources;
- Impacts and vulnerability will vary by region, as will the resources available to respond to climate change, necessitating regional solutions to adaptation rather than the proverbial one-size-fits-all approach; and
- An array of adaptive water management strategies, such as those outlined in this White Paper, must be implemented to better address the risk and uncertainty of changing climate patterns.

California's water crisis

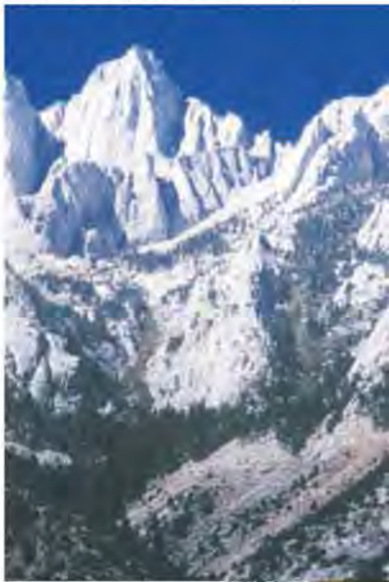
The history of water in California is one of conflict and perseverance. Concerns over the availability, quality and distribution of water are not new, but those concerns are growing. Solutions are becoming more complex as water managers navigate competing interests to reliably provide quality water to farms, businesses, and homes, while managing floods, protecting the environment, and complying with legal and regulatory requirements.

California water management includes an array of complicated issues. For example, the Sacramento-San Joaquin Delta, the hub of the state's water supply and delivery system and a crossroads of other critical infrastructure, faces serious ecosystem problems and substantial seismic risk that threaten water supply reliability and quality. Many groundwater basins suffer from overdraft and pollution. The Colorado River, an important source of water for Southern California, has suffered an historic drought that has helped to highlight the changing hydrology and its impact on water supplies. Throughout California, flood risk grows as levees age and more people live and work in floodplains, and changing climate yields higher flood flows.

What's happened already?

While the exact conditions of future climate change remain uncertain, there is no doubt about the changes that have already happened. Analysis of paleoclimatic data (such as tree-ring reconstructions of streamflow and precipitation) indicates a history of naturally and widely varying hydrologic conditions in California and the west, including a pattern of recurring and extended droughts. The average early spring snowpack in the Sierra Nevada decreased by about 10 percent during the last century, a loss of 1.5 million acre-feet of snowpack storage (one acre-foot of water is enough for one to two familes for one year). During the same period, sea level rose seven inches along California's coast. California's temperature has risen 1° F, mostly at night and during the winter, with higher elevations experiencing the highest increase. A disturbing pattern has also emerged in flood patterns; peak natural flows have increased on many of the state's rivers during the last 50 years. At the other extreme, many Southern California cities have experienced their lowest recorded annual precipitation twice within the past decade. In a span of only two years, Los Angeles experienced both its driest and wettest years on record.

Bottom: *Sacramento River*
Below: *Snowpack on Mt. Whitney*



THE CHALLENGES AHEAD

The trends of the last century – especially the increases in hydrological variability – will likely intensify this century, and abrupt changes in climate could also occur. The Intergovernmental Panel on Climate Change (IPCC) notes that the western United States may be especially vulnerable to water shortages. While the existing system has some capacity to cope with climate variability, extreme weather events resulting in increased droughts and floods will strain that capacity to meet future needs. California has invested in, and now depends upon, a system that relied on historical hydrology as a guide to the future for water supply and flood protection. However, due to climate change, the hydrology of the past is no longer a reliable guide to the future.

Rising temperatures affect California's snowpack levels

Loss of natural snowpack storage

One of the most critical impacts for California water management may be the projected reduction in the Sierra Nevada snowpack – California's largest surface "reservoir." Snowmelt currently provides an annual average of 15 million acre-feet of water, slowly released between April and July each year. Much of the state's water infrastructure was designed to capture the slow spring runoff and deliver it during the drier summer and fall months. Based upon historical data and modeling, DWR projects that the Sierra snowpack will experience a 25 to 40 percent reduction from its historic average by 2050. Climate change is also anticipated to bring warmer storms that result in less snowfall at lower elevations, reducing the total snowpack.

Historical and Future Hydrology

Use of historical hydrologic data has long been the standard of practice for designing and operating water supply and flood protection projects. For example, historical data are used for flood forecasting models such as the National Weather Service's River Forecast System Model and to forecast snowmelt runoff for water supply. This method of forecasting assumes climate "stationarity" – that the climate of the future will be similar to that of the relatively brief period of historical hydrologic record.

Paleoclimatology (which relies upon records from ice sheets, tree rings, sediment, and rocks to determine the past state of Earth's climate system), as well as other research revealing expected impacts of climate change, indicate that our traditional hydrologic approach can no longer be solely relied upon. That is, the hydrologic record cannot be used to predict expected increases in frequency and severity of extreme events such as floods and droughts. Going forward, model calibration or statistical relation development must happen more frequently, new forecast-based tools must be developed, and a standard of practice that explicitly considers climate change must be adopted.

Drought

Warming temperatures, combined with changes in rainfall and runoff patterns will exacerbate the frequency and intensity of droughts. Regions that rely heavily upon surface water (rivers, streams, and lakes) could be particularly affected as runoff becomes more variable, and more demand is placed on groundwater. Combined with urbanization expanding into wildlands, climate change will further stress the state's forests, making them more vulnerable to pests, disease and changes in species composition. Along with drier soils, forests will experience more frequent and intense fires, resulting in subsequent changes in vegetation, and eventually a reduction in the water supply and storage capacity benefits of a healthy forest.

Climate change will also affect water demand. Warmer temperatures will likely increase evapotranspiration rates and extend growing seasons, thereby increasing the amount of water that is needed for the irrigation of many crops, urban landscaping and environmental water needs. Reduced soil moisture and surface flows will disproportionately affect the environment and other water users that rely only on annual rainfall such as non-irrigated agriculture, livestock grazing on non-irrigated rangeland and recreation.

Floods

The amount of snow is critical for water supply and environmental needs, but so is the timing of snowmelt runoff into rivers and streams. Rising snowlines caused by climate change will allow more of the Sierra Nevada watersheds to contribute to peak storm runoff. High frequency flood events (e.g. 10-year floods) in particular will likely increase with a changing climate. Along with reductions in the amount of the snowpack and accelerated snowmelt, scientists project greater storm intensity, resulting in more direct runoff and flooding. Changes in watershed vegetation and soil moisture conditions will likewise change runoff and recharge patterns. As streamflows and velocities change, erosion patterns will also change, altering channel shapes and depths, possibly increasing sedimentation behind dams, and affecting habitat and water quality.
With potential increases in the frequency and intensity of wildland fires due to climate change, there is a potential for more floods following fire, which increase sediment loads and water quality impacts.

The Colorado River

Climate research in the Colorado River basin has shown that natural climate variability alone has resulted in droughts far more severe than those in the basin's measured historical record. Understanding additional impacts of climate change on the Southwest's most important river basin has been a subject of ongoing interest in the academic community. In addition to impacts on runoff, anticipated warming in the arid Southwest is also expected to increase water demands.

For the purposes of federal flood insurance, the Federal Emergency Management Agency (FEMA) has traditionally used the 100-year flood event, which refers to the level of flood flows that has a one-percent chance of being exceeded in any single year. As California's hydrology changes, what is currently considered a 100-year flood may strike more often, leaving many communities at greater risk. Moreover, as peak flows and precipitation change over time, climate change calls into question assumptions of "stationarity" that is used in flood-related statistical analyses like the 100-year flood (see sidebar on page 4). Planners will need to factor a new level of safety into the design, operation, and regulation of flood protection facilities such as dams, floodways, bypasses and levees, as well as the design of local sewers and storm drains.

Water quality

Changes in the timing of river flows and warming atmospheric temperatures may affect water quality and water uses in many different ways. At one extreme, flood peaks may cause more erosion, resulting in turbidity and concentrated pulses of pollutants. This will challenge water treatment plant operations to produce safe drinking water. Flooding can also threaten the integrity of water works infrastructure. At the other extreme, lower summer and fall flows may result in greater concentration of contaminants. These changes in streamflow timing may require new approaches to discharge permitting and non-point source pollution. Warmer water will distress many fish species and could require additional cold water reservoir releases. Higher water temperatures can also accelerate some biological and chemical processes, increasing growth of algae and microorganisms, the depletion of dissolved oxygen, and various impacts to water treatment processes. An increase in the frequency and intensity of wildfires will also affect watersheds, vegetation, runoff and water quality.

Sea level rise

Sea levels are rising, and it is generally accepted that this trend will continue. However, the exact rate of rise is unknown, due to ongoing scientific uncertainty about the melting of ice sheets on western Antarctica and Greenland and the potential for abrupt changes in ocean conditions. Recent peer-reviewed studies estimate a rise of between seven to 55 inches by 2100 along California's coast.

Winter storm in southern Sierra Nevada mountain range

The implications of a seven-inch rise are dramatically different than a rate of rise towards the upper end of the range. However, even a rise at the lower end of this range poses an increased risk of storm surge and flooding for California's coastal residents and infrastructure, including many of the state's wastewater treatment plants. Moreover, sea level rise can contribute to catastrophic levee failures in the Delta, which have great potential to inundate communities, damage infrastructure, and interrupt water supplies throughout the state.

Even without levee failures, Delta water supplies and aquatic habitat will be affected due to saltwater intrusion. An increase in the penetration of seawater into the Delta will further degrade drinking and agricultural water quality and alter ecosystem conditions. More freshwater releases from upstream reservoirs will be required to repel the sea to maintain salinity levels for municipal, industrial and agricultural uses. Alternatively, changes in upstream and in-Delta diversions, exports from the Delta, and improved conveyance through or around the Delta may be needed. Sea level rise may also affect drinking water supplies for coastal communities due to the intrusion of seawater into overdrafted coastal aquifers.

Hydroelectric generation

Climate change will reduce the reliability of California's hydroelectricity operations, which, according to the California Climate Action Registry and the California Air Resources Board, is the state's largest source of greenhouse gas emissions-free energy. Changes in the timing of inflows to reservoirs may exceed generation capacity, forcing water releases over spillways and resulting in lost opportunities to generate hydropower. Higher snow elevations, decreased snowpack, and earlier melting may result in less water available for clean power generation during hot summer months, when energy demand is highest. The impact is compounded overall by anticipated increased energy consumption due to higher temperatures and greater water demands in summer when less water is available. The potential for lengthier droughts may also lower reservoir levels below that which is necessary for power generation.

Thermalito Diversion Dam Powerplant

Dam Safety

Implemented by DWR's Division of Safety of Dams (DSOD), California has one of the most comprehensive dam safety programs in the world.

Preliminary assessments by DSOD of how climate change may potentially impact dam safety reveal that increased safety precautions may be needed to adapt systems to higher winter runoff, frequent fluctuation of water levels, and the potential for additional sediment and debris from drought-related fires. Additionally, climate change will impact the ability of dam operators to estimate extreme flood events.

THE IMPERATIVE TO ACT

As understanding of climate change improves, the challenge for California's water community is to develop and implement strategies that improve resiliency, reduce risk, and increase sustainability for water and flood management systems and the ecosystems upon which they depend.

California water management systems have provided the foundation for the state's economic vitality for more than 100 years, providing water supply, sanitation, electricity, recreation and flood protection.

With the state's water resources already stressed, additional stress from climate change will only intensify the competition for clean, reliable water supplies. While doing its part to reduce greenhouse gas emissions and expand the use of clean energy sources, California's water community must concentrate on adaptation strategies to respond to the anticipated changes. The IPCC's Fourth Assessment Report (2007) states that adaptation "will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions." As understanding of climate change improves, the challenge for California's water community is to develop and implement strategies that improve resiliency, reduce risk, and increase sustainability for water and flood management systems and the ecosystems upon which they depend.

Governor Schwarzenegger signing the Global Warming Solutions Act (AB 32) in 2006

Mitigation Response

The mitigation response to climate change, or the reduction of greenhouse gas emissions that contribute to our changing climate, has received more international attention to date than adaptation. On a global scale, greenhouse gas emissions must be reduced to slow the effects of warming and climate change. California is leading the nation to enact major greenhouse gas reductions on an ambitious timeline. In 2006, Governor Arnold Schwarzenegger and the California Legislature enacted Assembly Bill (AB) 32 - The Global Warming Solutions Act. The law requires a statewide cap on greenhouse gas emissions, reductions in emissions from major sources, and the development of a mandatory reporting system for these emissions.

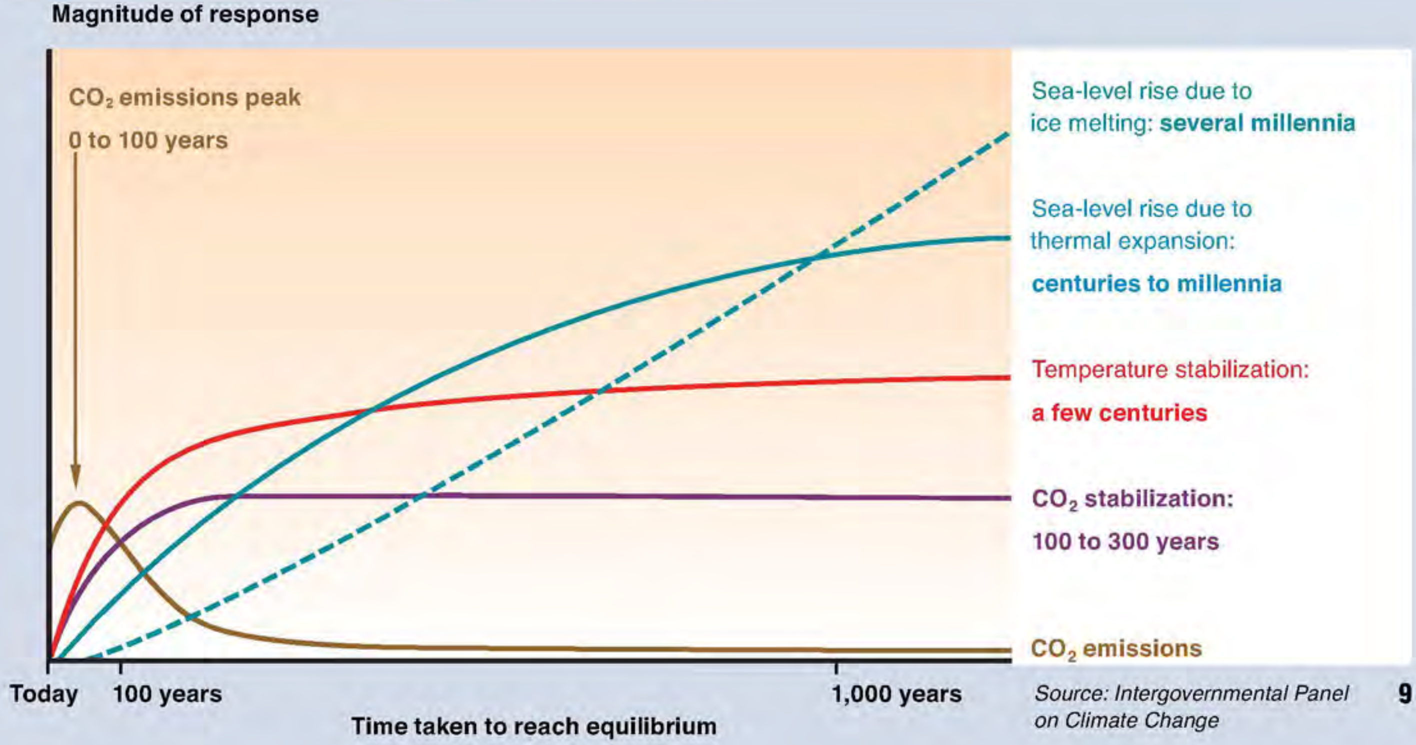
While water generates much of the state's electricity, according to the California Energy Commission (CEC), water-related energy use in California also consumes approximately 20 percent of the state's electricity, and 30 percent of the state's non-power plant natural gas (i.e. natural gas not used to produce electricity). The CEC also found that most of the energy intensity of water use in California is in the end uses by the customer (e.g. heating, processing, and pressurizing water). In fact, the CEC states that 75 percent of the electricity and nearly all of the natural gas use related to water in California is associated with the end use of water, mostly for water heating.

The Governor's Climate Action Team is overseeing the implementation of AB 32 including a multi-agency Water-Energy subgroup tasked with the development of greenhouse gas mitigation strategies for energy consumption related to water use.

Fortunately, there are multiple strategies that can help reduce the risks presented by climate change. To be successful, these adaptation strategies must be well-coordinated at the state, regional and local levels in order to maximize their effect. No single project or strategy can adequately address the challenges California faces, and tradeoffs must be explicitly acknowledged and decided upon. That said, planning and investing now in a comprehensive set of actions that informs water managers and provides system diversity and resilience will help prepare California for future climate uncertainty.

The Real McCoy ferry crossing Cache Slough, carrying traffic just upstream of Rio Vista

CO_2 concentration, temperature, and sea level continue to rise long after emissions are reduced



Source: Intergovernmental Panel on Climate Change

ADAPTATION STRATEGIES

The following pages present 10 climate change adaptation strategies for California's water. The strategies fall under four major categories: Investment, Regional, Statewide and Improving Management and Decision-Making Capacity.

...climate change presents an ongoing risk that requires a long-term commitment of funding that is properly matched to anticipated expenditures, beneficiaries and responsible parties.

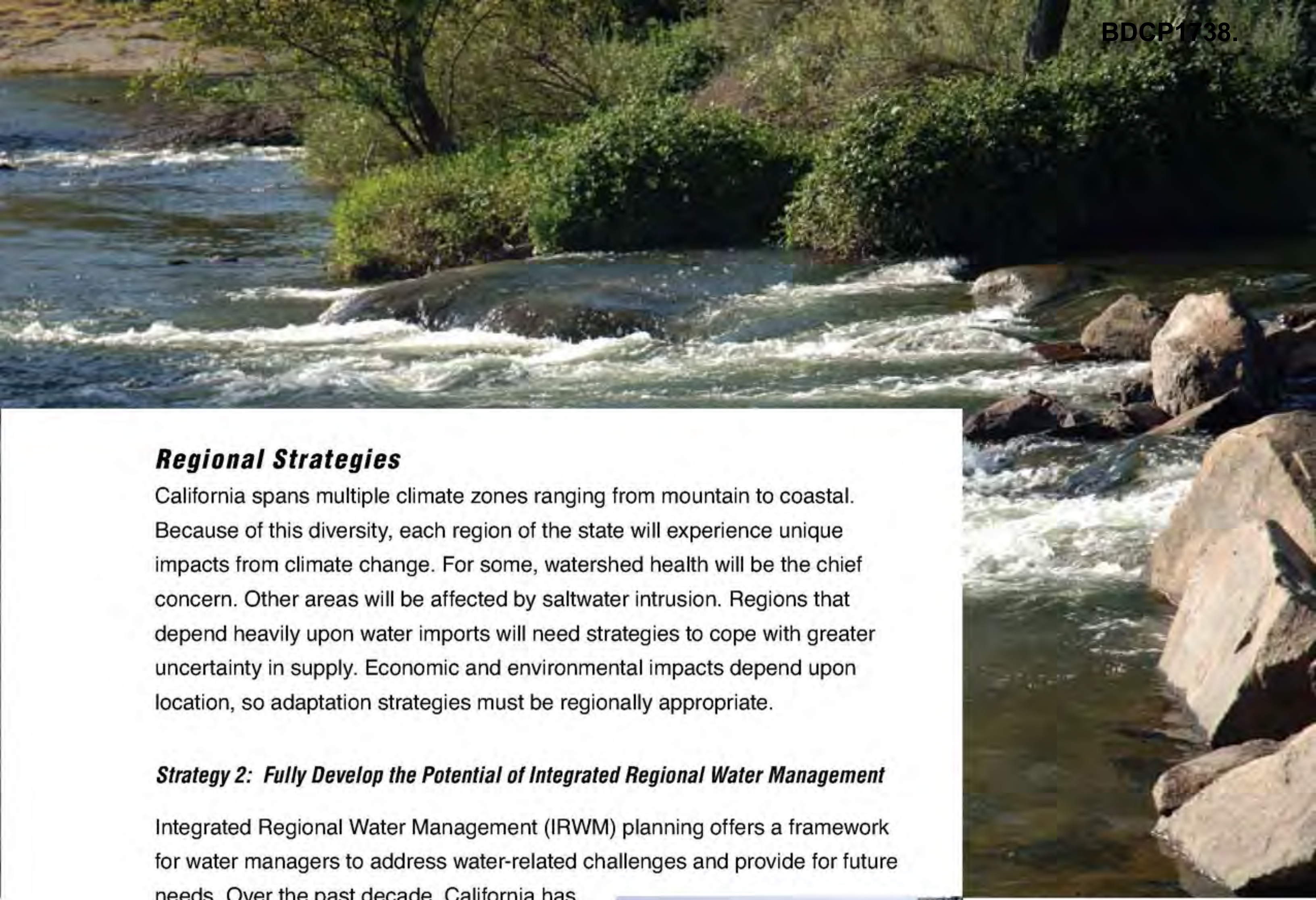
Investment Strategy

Adaptive responses to climate change will not come without a cost. Climate change magnifies the problems that exist with an aging water infrastructure and growing population. While recent bond measures have provided a down payment for improving California's water and flood systems, climate change presents an ongoing risk that requires a long-term commitment of funding that is properly matched to anticipated expenditures, beneficiaries and responsible parties.

Strategy 1: Provide Sustainable Funding for Statewide and Integrated Regional Water Management

- The State Legislature should initiate a formal assessment of state and local financing mechanisms to provide a continuous and stable source of revenue to sustain the programs described herein. Activities in particular need of certainty and continuity in funding include regional water planning, inspection, maintenance, repair, and rehabilitation of flood management facilities, observational networks and water-related climate change adaptation research.

Levee repair site on Sacramento River



San Joaquin River

Regional Strategies

California spans multiple climate zones ranging from mountain to coastal. Because of this diversity, each region of the state will experience unique impacts from climate change. For some, watershed health will be the chief concern. Other areas will be affected by saltwater intrusion. Regions that depend heavily upon water imports will need strategies to cope with greater uncertainty in supply. Economic and environmental impacts depend upon location, so adaptation strategies must be regionally appropriate.

Strategy 2: Fully Develop the Potential of Integrated Regional Water Management

Integrated Regional Water Management (IRWM) planning offers a framework for water managers to address water-related challenges and provide for future needs. Over the past decade, California has improved its understanding of the value of regional planning and made significant steps to implement IRWM. Formally, IRWM is a comprehensive approach for determining the appropriate mix of water demand and supply management options and water quality actions. This approach provides reliable water supplies at lowest reasonable cost and with highest benefits for economic development, environmental quality and other societal objectives. Moreover, if appropriately developed and implemented, IRWM plans—in combination with other regional planning efforts for transportation and land use—can serve as the basis for broader community adaptation plans for climate change.

Suspended irrigation system

The state will encourage—through both financial and technical assistance—IRWM planning and implementation activities that adapt water management to a changing climate.

- By 2011, all IRWM plans should identify strategies that can improve the coordination of local groundwater storage and banking with local surface storage and other water supplies such as recycled municipal water, surface runoff and floodflows, urban runoff and stormwater, imported water, water transfers, and desalinated groundwater and seawater.

- By 2011, all IRWM plans should include specific elements to adapt to a changing climate, including:
    - An assessment of the region's vulnerability to the long-term increased risk and uncertainty associated with climate change.
        - An integrated flood management component.
        - A drought component that assumes, until more accurate information is available, a 20 percent increase in the frequency and duration of future dry conditions.
    - Aggressive conservation and efficiency strategies.
    - Integration with land use policies that:
        - Help restore natural processes in watersheds to increase infiltration, slow runoff, improve water quality and augment the natural storage of water.
        - Encourage low-impact development that reduces water demand, captures and reuses stormwater and urban runoff, and increases water supply reliability.
    - A plan for entities within a region to share water supplies and infrastructure during emergencies such as droughts.

- Large water and wastewater utilities should conduct an assessment of their carbon footprint and consider implementation of strategies described in the draft AB 32 Scoping Plan to reduce greenhouse gas emissions. To take advantage of an existing framework and process for calculating their carbon footprint, these utilities should join the Climate Action Registry.

IRWM is a comprehensive approach for determining the appropriate mix of water demand and supply management options and water quality actions to provide reliable water supplies at lowest reasonable cost and with highest benefits for economic development, environmental quality and other societal objectives.

Strategy 3: Aggressively Increase Water Use Efficiency

Using water efficiently is a foundational action for water management, one that serves to mitigate and adapt to climate change. Water conservation reduces water demand, wastewater discharges, and can reduce energy demand and greenhouse gas emissions. Efficient water use can help communities cope with water shortages that may result from climate change, thus reducing economic and environmental impacts of water shortages. Water use efficiency must be a cornerstone of every water agency's water portfolio.

- As directed by Governor Schwarzenegger, DWR in collaboration with the Water Boards, the California Energy Commission (CEC), the California Public Utilities Commission, the California Department of Public Health, and other agencies, are developing and will implement strategies to achieve a statewide 20 percent reduction in per capita water use by 2020.
  - By 2010, all Urban Water Management Plans must include provisions to fund and implement all economic, feasible, and legal urban best management practices established by the California Urban Water Conservation Council (CUWCC) (see sidebar).

Drought tolerant landscaping in Southern California

Model Water Efficient Landscape Ordinance

The Water Conservation in Landscaping Act of 2006, Assembly Bill 1881, requires DWR to update the existing Model Water Efficient Landscape Ordinance (model ordinance) and adopt the model ordinance by January 1, 2009. Each local agency is required to adopt either the updated model ordinance or its own local landscape ordinance that is at least as effective by January 1, 2010. DWR is developing the updated model ordinance to reflect new technology and advances in landscape water management and to increase outdoor water conservation through improved landscape design, management and maintenance. The ordinance provides guidance to local agencies in developing and adopting landscape ordinances leading to water savings, which will reduce water demand, waste and water-related energy use.

Conservation

Urban Best Management Practices

In 1991, water suppliers and environmental organization members of the CUWCC reached agreement on a series of Best Management Practices (BMPs) that define urban water conservation measures and implementation levels. The BMPs define required actions or goals and are now widely accepted as the minimum level of conservation effort for most water suppliers in California. The BMPs are intended to reduce long-term urban demands from what they would have been without implementation of these practices.
The 14 BMPs include residential ultra-low flush toilet replacement programs, conservation pricing, large landscape conservation, and high efficiency clothes washer rebates.

The CUWCC is currently in the process of revising and updating the BMPs. More information is at **www.cuwcc.org**.

Conservation

Agricultural Efficient Water Management Practices

In 1996, the Agricultural Water Management Council prepared a list of agricultural water best management practices known as "Efficient Water Management Practices" (EWMPs). The EWMPs fall under three major categories: generally applicable, conditionally applicable and other, and include the following:

- preparation and adoption of a water management plan
- pump testing and evaluation
- canal and ditch lining
- implementation of tail-water recovery systems
- use of real-time irrigation scheduling and evapotranspiration data
- beneficial use of recycled water
- optimization of conjunctive use of ground water and surface water supplies
- incentivized pricing

Additional information and the full list of the EWMPs can be found online at **www.agwatercouncil.org**.

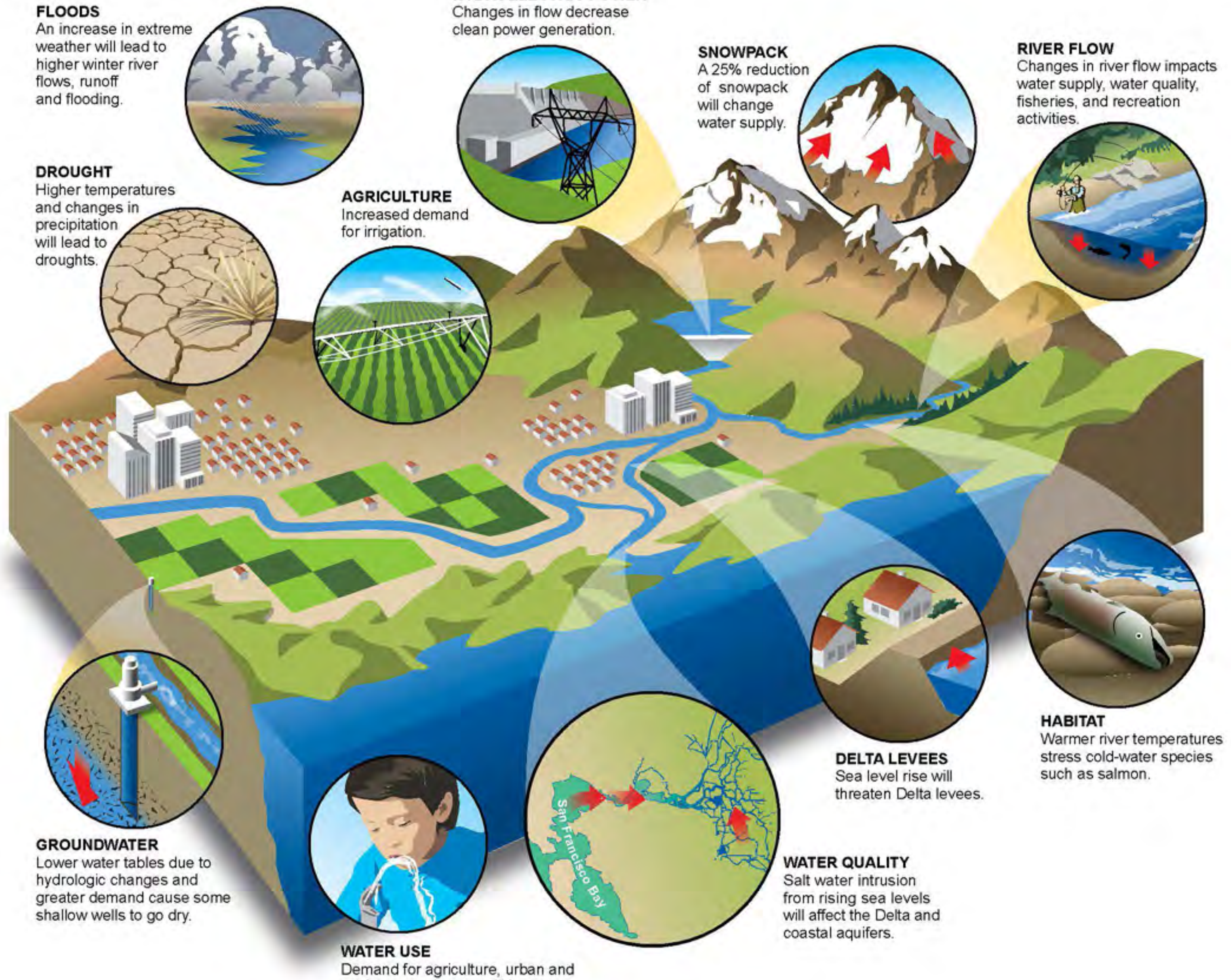
- All local governments are required by statute to adopt the State Model Water Efficient Landscape Ordinance (MWELO) or equivalent (see sidebar). Because the model ordinance only addresses new development, local governments must pursue conservation programs to reduce water use on existing landscapes.
- Notwithstanding other water management objectives, local and regional water use efficiency programs—agricultural, residential, commercial, industrial and institutional—should emphasize those measures that reduce both water and energy consumption.

These agencies, in coordination with the rest of the Water-Energy subgroup of the Governor's Climate Action Team and the CUWCC, will develop urban water use efficiency recommendations for incorporation into the California Water Plan Update 2009.

- Agricultural entities should apply all feasible Efficient Water Management Practices (EWMPs) to reduce water demand and improve the quality of drainage and return flows, and report on implementation in their water management plans.
- Recycled water is a drought-proof water management strategy that may also be an energy efficient option in some regions.
  - In those regions, wastewater and water agencies should collaboratively adopt policies and develop facility plans that promote the use of recycled water for all appropriate, cost-effective uses while protecting public health.
  - In consultation with DWR and the Department of Public Health, the Water Boards should identify opportunities to optimize water recycling consistent with existing permitting authority.

The State Water Resources Control Board (SWRCB) and the California Public Utilities Commission are authorized to impose water conservation measures in permitting and other proceedings to ensure attainment of these conservation efforts. Additionally, the Legislature should authorize and fund new incentive-based programs to promote the widespread and mainstream adoption of aggressive water conservation by urban and agricultural water systems and their users.

How climate change impacts a watershed



FLOODS
An increase in extreme weather will lead to higher winter river flows, runoff and flooding.

HYDROELECTRIC POWER
Changes in flow decrease clean power generation.

SNOWPACK
A 25% reduction of snowpack will change water supply.

RIVER FLOW
Changes in river flow impacts water supply, water quality, fisheries, and recreation activities.

DROUGHT
Higher temperatures and changes in precipitation will lead to droughts.

AGRICULTURE
Increased demand for irrigation.

HABITAT
Warmer river temperatures stress cold-water species such as salmon.

DELTA LEVEES
Sea level rise will threaten Delta levees.

GROUNDWATER
Lower water tables due to hydrologic changes and greater demand cause some shallow wells to go dry.

WATER QUALITY
Salt water intrusion from rising sea levels will affect the Delta and coastal aquifers.

WATER USE
Demand for agriculture, urban and environmental water will increase.

Oroville Dam

Statewide Strategies

California has an unparalleled water infrastructure system that stores and conveys water, manages flood flows, and interconnects many of the state's regions. However, current water resources infrastructure is already strained to meet existing, competing objectives for water supply, flood protection, environmental protection, water quality, hydropower and recreation. In a changing climate, the conflicts between competing interests are even greater as supplies become less reliable. This system of reservoirs, canals, flood bypasses and levees must be modified and managed differently to accommodate the increased variability brought by climate change. As the prediction of climate change impacts will never be perfect, flexibility must be a fundamental tactic, especially regarding water system operations.

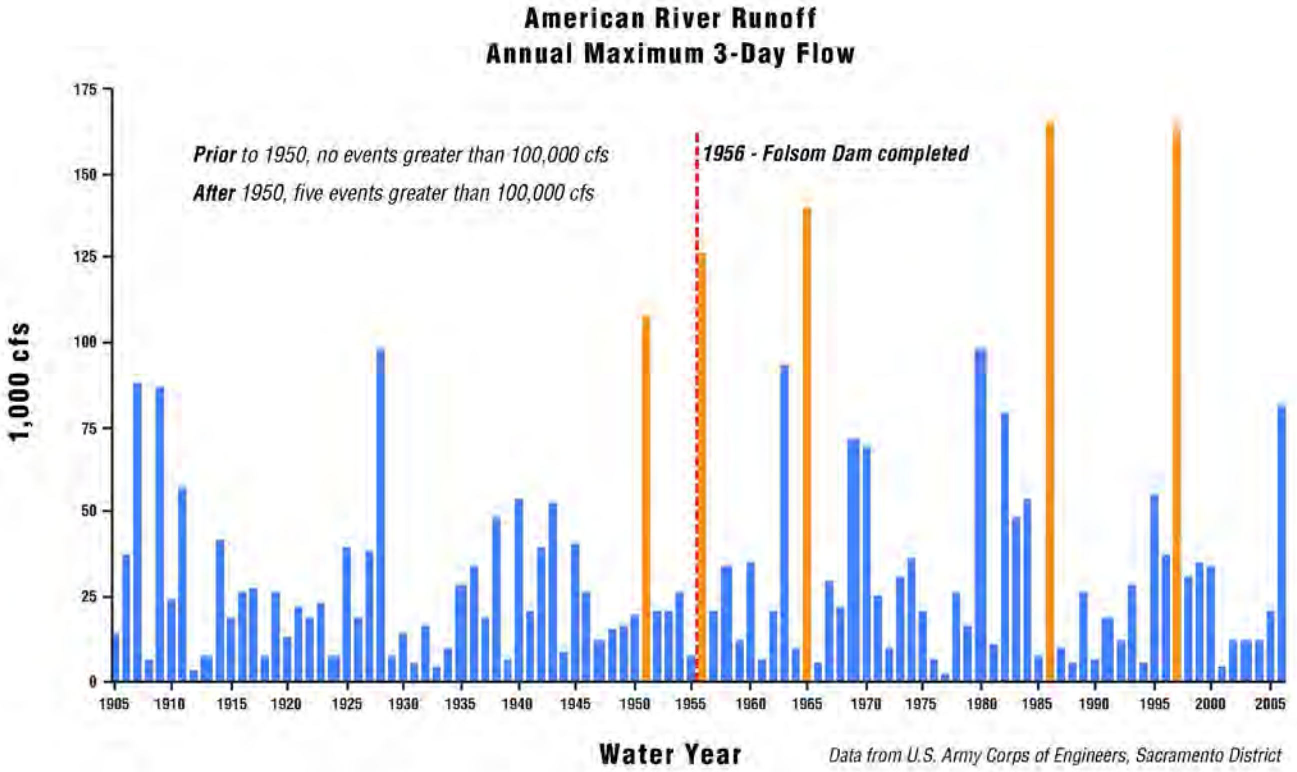
Flood systems throughout the state must be upgraded and managed to accommodate the higher variability of flood flows, to protect public safety, the economy and ecosystems.

Strategy 4: Practice and Promote Integrated Flood Management

Many Californians already face an unacceptable risk of flooding. Catastrophic flooding within the Central Valley could mirror the economic, social and environmental damages caused by Hurricane Katrina in 2005. Millions of people in California's Central Valley live behind or depend upon levees to protect them, with populations in these regions continuing to grow. Climate change will increase the state's flood risk by causing a shift toward more intense winter storms which could produce higher peak flows. Flood systems throughout the state must be upgraded and managed to accommodate the higher variability of flood flows, to protect public safety, the economy and ecosystems.

- Flood management systems must better utilize natural floodplain processes. Thus, flood management should be integrated with watershed management on open space, agricultural, wildlife areas, and other low density lands to lessen flood peaks, reduce sedimentation, temporarily store floodwaters and recharge aquifers, and restore environmental flows.

Liberty Island



Data from U.S. Army Corps of Engineers, Sacramento District

The five highest floods of record on the American River have occurred since 1950.

The improved performance of existing water infrastructure cannot be achieved by any single agency, and will require the explicit cooperation of many agencies. Systemwide operational coordination and cooperation must be streamlined to respond to extreme events that may result from climate change. Successful system reoperation will require that the benefits and tradeoffs of such actions are evident to federal and local partners.

- The state will establish a System Reoperation Task Force comprised of state personnel, federal agency representatives and appropriate stakeholders that will:
  - Quantify the potential costs and benefits and impacts of system reoperation for water supply reliability, flood control, hydropower, water quality, fish passage, cold water management for fisheries and other ecosystem needs;

System Reoperation

California's water resources system includes both physical elements (such as reservoirs, aquifers, rivers, pumping plants, and canals) and non-physical elements (such as operating rules, land use practices, and environmental regulations). The addition or removal of a structural element or a change in a non-structural element often provides opportunities to optimize the operational benefits of other elements of the system.

The key to system reoperation is to integrate and connect individual system elements to illustrate how changes in use of one element can be balanced by changes in the use of other elements.

The largest challenge to system reoperation is that individual system elements are often owned and operated by independent entities.

  - Support the update of U.S. Army Corps of Engineers' operations guidelines for Central Valley reservoirs;
  - Support the update of flood frequency analyses on major rivers and streams;
  - Evaluate the need to amend flow objectives;
  - Expand the study of forecast-based operations for incorporation into reservoir operations;
  - Include watershed level analyses that detail localized costs and benefits; and
  - Identify key institutional obstacles that limit benefits.

- To coordinate California's water supply and flood management operations, state and federal agencies collaboratively established the Joint Operations Center (JOC). To successfully meet the challenges posed by climate change, the JOC capacity must be expanded to improve tools and observations to better support decision-making for individual events and seasonal and interannual operations, including water transfers. The JOC should be enhanced to further improve communications and coordination during emergencies, such as floods and droughts.

- By January 1, 2012, DWR will collaboratively develop a Central Valley Flood Protection Plan that includes actions to improve integrated flood management and considers the expected impacts of climate change. The plan will provide strategies for greater flood protection and environmental resilience, including:
  - Emergency preparedness, response, evacuation and recovery actions;
  - Opportunities and incentives for expanding, or increasing the use of floodway corridors to reduce stress on critical urban levees and provide for habitat, open space, recreation and agricultural land preservation;
  - Options and recommendations to provide at least 200-year level protection for all urban areas within the Sacramento-San Joaquin Valley;

  - Increased use of setback levees, flood easements, zoning, and land acquisitions to provide greater public safety, floodplain storage, habitat and system flexibility;
  - Flood insurance requirements to address residual risk;
  - Extensive, grassroots public outreach and education; and
  - The integration of flood management with all aspects of water resources management and environmental stewardship.

- All at-risk communities should develop, adopt, practice and regularly evaluate formal flood emergency preparedness, response, evacuation and recovery plans.

- Local governments should implement land use policies that decrease flood risk.
  - Local land use agencies should update their General Plans to address increased flood risks posed by climate change. General Plans should consider an appropriate risk tolerance and planning horizon for each locality.
  - Local governments should site new development outside of undeveloped floodplains unless the floodplain has at least a sustainable, 200-year level of flood protection.
  - Local governments should use low-impact development techniques to infiltrate and store runoff.
  - Local governments should include flood-resistant design requirements in local building codes.

Adaptive Capacity and Resilience

Adaptive capacity is the ability of systems, organizations, and individuals to:

- adjust to actual or potential adverse changes and events,
- take advantage of existing and emerging opportunities that support essential functions or relationships, and/or
- cope with adverse consequences, mitigate damages, and recover from system failures.

Resilience is the capacity of a resource or natural system to return to prior conditions after a disturbance.

Levee break at Jones Tract

Engineer reviews flood data at DWR's Joint Operations Center

California Conservation Corps workers strengthen a levee during a high water event

FloodSAFE CALIFORNIA

FloodSAFE California is a multi-faceted, strategic initiative to improve public safety through integrated flood management. Primarily funded by Propositions 1E and 84, the FloodSAFE program is a collaborative statewide effort to accomplish the following five broad goals:

Reduce the Chance of Flooding
Reduce the frequency and size of floods that could damage California communities, homes and property, and critical public infrastructure.

Reduce the Consequences of Flooding
Take actions prior to flooding that will help reduce the adverse consequences of floods when they do occur and allow for quicker recovery after flooding.

Sustain Economic Growth
Provide continuing opportunities for prudent economic development that supports robust regional and statewide economies without creating additional flood risk.

Protect and Enhance Ecosystems
Improve flood management systems in ways that protect, restore, and where possible, enhance ecosystems and other public trust resources.

Promote Sustainability
Take actions that improve compatibility with the natural environment and reduce the expected costs to operate and maintain flood management systems into the future.

Additional information is available at **www.water.ca.gov/floodsafe**.

Setback levee being constructed near Bear River

Strategy 5: Enhance and Sustain Ecosystems

Reliable water supplies and resilient flood protection depend upon ecosystem sustainability. Building adaptive capacity for both public safety and ecosystems requires that water and flood management projects maintain and enhance biological diversity and natural ecosystem processes. Water supply and flood management systems are significantly more sustainable and economical over time when they preserve, enhance and restore ecosystem functions, thereby creating integrated systems that suffer less damage from, and recover more quickly after, severe natural disruptions. By reducing existing, non-climate stressors on the environment, ecosystems will have more capacity to adapt to new stressors and uncertainties brought by climate change.

- Water management systems should protect and reestablish contiguous habitat and migration and movement corridors for plant and animal species related to rivers and riparian or wetland ecosystems. IRWM and regional flood management plans should incorporate corridor connectivity and restoration of native aquatic and terrestrial habitats to support increased biodiversity and resilience for adapting to a changing climate.
- Flood management systems should seek to reestablish natural hydrologic connectivity between rivers and their historic floodplains. Setback levees and bypasses help to retain and slowly release floodwater, facilitate groundwater recharge, provide seasonal aquatic habitat, support corridors of native riparian forests and create shaded riverine and terrestrial habitats. Carbon sequestration within large, vegetated floodplain corridors may also assist the state in meeting greenhouse gas emissions reductions mandated by AB 32.
- The state should work with dam owners and operators, federal resource management agencies, and other stakeholders to evaluate opportunities to introduce or reintroduce anadromous fish to upper watersheds. Reestablishing anadromous fish, such as salmon, upstream of dams may provide flexibility in providing cold water conditions downstream, and thereby help inform system reoperation. Candidate watersheds should have sufficient habitat to support spawning and rearing of self-sustaining populations.

Sheep grazing in the Yolo Bypass, west of Sacramento

- The state should identify and strategically prioritize for protection lands at the boundaries of the San Francisco Bay and Sacramento-San Joaquin Delta that will provide the habitat range for tidal wetlands to adapt to sea level rise. Such lands help maintain estuarine ecosystem functions and create natural land features that act as storm buffers, protecting people and property from flood damages related to sea level rise and storm surges.
- The state should prioritize and expand Delta island subsidence reversal and land accretion projects to create equilibrium between land and estuary elevations along select Delta fringes and islands. Sediment-soil accretion is a cost-effective, natural process that can help sustain the Delta ecosystem and protect Delta communities from inundation.
- The state should consider actions to protect, enhance and restore upper watershed forests and meadow systems that act as natural water and snow storage. This measure not only improves water supply reliability and protects water quality, but also safeguards significant high elevation habitats and migratory corridors.

Left: *Sacramento-San Joaquin Delta, with Mount Diablo in background*

Below: *Los Vaqueros Reservoir*

Strategy 6: Expand Water Storage and Conjunctive Management of Surface and Groundwater Resources

Surface and groundwater resources must be managed conjunctively to meet the challenges posed by climate change. Additional water storage and conveyance improvements are necessary to provide flexibility to facilitate water transfers between regions and to provide better flood management, water quality and system reliability, in response to daily and seasonal variations and uncertainties in water supply and use.

Historically, California has depended upon its groundwater, particularly during droughts. However, many aquifers are contaminated and must be remediated before they can be used as water banks. Groundwater resources will not be immune to climate change; in fact, historic patterns of groundwater recharge may change considerably. Climate change may worsen droughts, so more efficient groundwater basin management will be necessary to avoid additional overdraft, to take advantage of opportunities to store water underground and eliminate existing overdraft.

Better management of surface storage reservoirs can also provide benefits in a changing climate. Among the benefits are capturing higher peak flows, providing cold water releases for fish, repulsing seawater intrusion to protect drinking water quality, generating clean hydroelectricity, and offsetting the loss of snowpack storage with increased water storage.

- California must expand its available water storage including both surface and groundwater storage.
- DWR will incorporate climate change considerations as it works with the U.S. Bureau of Reclamation (Reclamation) and local agencies to complete surface storage feasibility studies and environmental documentation for the Sites Reservoir and Upper San Joaquin River Basin Storage Investigations. DWR will also make climate change recommendations as it works cooperatively with Contra Costa Water District on the Los Vaqueros Reservoir Expansion Investigation, and DWR will advise Reclamation on climate change matters on the Shasta Lake Water Resources Investigation.

Conjunctive Management

Conjunctive management of surface water and groundwater refers to the joint and coordinated management of both resources. Surface water and groundwater resources typically differ significantly in their availability, quality, management needs, and development and use costs. Managing both resources together, rather than in isolation from one another, allows water managers to use the advantages of both resources for maximum benefit.

Groundwater pump

- State, federal, and local agencies should develop conjunctive use management plans that integrate floodplain management, groundwater banking and surface storage. Such plans could help facilitate system reoperation and provide a framework for the development of local projects that are beneficial across regions.

- Local agencies should develop and implement AB 3030 Groundwater Management Plans as a fundamental component of IRWM plans. Local agencies must have such groundwater management plans to:
    - Effectively use aquifers as water banks;
    - Protect and improve water quality;
    - Prevent seawater intrusion of coastal aquifers caused by sea level rise;
    - Monitor withdrawals and levels;
    - Coordinate with other regional planning efforts to identify and pursue opportunities for interregional conjunctive management;
    - Avert otherwise inevitable conflicts in water supply; and
    - Provide for sustainable groundwater use.

Irrigation in California's Central Valley

- Local land use agencies should adopt ordinances that protect the natural functioning of groundwater recharge areas.

Strategy 7: Fix Delta Water Supply, Quality and Ecosystem Conditions

The Sacramento-San Joaquin Delta is a vital water supply for 25 million Californians, a diverse and complex ecosystem, home to many communities and ultimately is a place unique to California. The Delta is not considered sustainable under current management efforts. Warmer temperatures, sea level rise and higher flood flows brought by climate change threaten to further erode the Delta's sustainability. The Delta Vision Task Force published its vision for the Delta in December 2007. In that vision, the Task Force described a future in which the Delta will continue to thrive over the coming generations, despite major challenges including climate change. The Task Force is working on a strategic plan that will outline the recommendations to realize the Task Force's vision.

In addition to the work of Delta Vision, there are three other major public processes also focusing on the Delta: the Bay-Delta Conservation Plan (BDCP), the Delta Risk Management Strategy (DRMS) and the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) (see next page).

- State agencies and stakeholders should continue to support the work of the Delta Vision Task Force, BDCP, DRMS, and DRERIP, and encourage the incorporation of adaptive responses to climate change for the Delta in all four processes.
- By June 2009, affected state agencies, led by DWR, will initiate a coordinated effort to invest in the Delta ecosystem, water conveyance improvements, flood protection and community sustainability in order to achieve a sustainable Delta.

Canadian Geese in Sacramento-San Joaquin Delta

Delta at sunset

Delta Planning Processes and Climate Change

State government is currently involved in four major planning efforts to evaluate Sacramento-San Joaquin Delta ecosystem and water supply issues and to recommend strategies and actions for their improvement — the Delta Vision, Bay-Delta Conservation Plan (BDCP), Delta Risk Management Strategy (DRMS), and Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). These efforts are complementary but each process has a specific focus. All are considering the impacts of climate change on the Delta as well as a number of response strategies. Together, they should provide a set of adaptive strategies and actions that are comprehensive, consistent and build upon each other to improve the Delta ecosystem and water supply reliability.

The Governor established **Delta Vision** in 2006 to develop a durable vision for sustainable management of the Delta. Over the long term, the Delta Vision process aims to restore and maintain functions and values that are determined to be important to the environmental quality of the Delta and the economic and social well being of the people of the state. In December 2007, the Delta Vision Task Force published its Delta Vision Report comprised of 12 recommendations and in October 2008, submitted their Delta Strategic Plan to the Delta Vision Cabinet Commitee. The Cabinet Commitee will provide specific recommendations to the Governor and Legislature by the end of 2008. More information is available at **www.deltavision.ca.gov**.

The purpose of the **BDCP** is to help recover endangered and sensitive species and their habitats in the Delta in a way that also provides for sufficient and reliable water supplies. The BDCP will (1) identify and implement conservation strategies to improve the overall ecological health of the Delta, (2) identify and implement ecologically friendly ways to move fresh water through and/or around the Delta, (3) address toxic pollutants, invasive species and impairments to water quality, and (4) provide a framework to implement the plan over time. More information is available at **www.resources.ca.gov/bdcp**.

DRMS is evaluating the risks from Delta levee failures and ways to reduce those risks. Preliminary evaluations by DRMS show that the risks from earthquakes and floods are substantial and are expected to increase in the future. In Phase 1, DRMS evaluates the risk and consequences to the Delta and statewide associated with the failure of Delta levees. In Phase 2, DRMS will evaluate strategies and actions to reduce risks and consequences. Additional information is available at **www.drms.water.ca.gov**.

The **DRERIP** is identifying restoration opportunities within the Delta and Suisun Marsh ecological restoration zones. It applies the Ecosystem Restoration Program Conservation Strategy to the Delta, refines existing and develops new Delta restoration actions, and includes a conceptual model, implementation guidance, program tracking, performance evaluation, and adaptive management feedback. Additional information at **www.delta.dfg.ca.gov/erpdeltaplan**.

Improving Management and Decision-Making Capacity

Determining the impacts of climate change on the varying regions of the state requires that data about our environment be collected and analyzed in a consistent and comprehensive way. Analysis of past records, current conditions, and trends can help provide a forecast for weather, climate, supply, and flooding variables. Unfortunately, sensors and gauges that measure this information, both offshore and over land, are currently inadequate. Strategic investment is needed in measurement networks, data analysis and archiving, and forecast tools that can support operational and policy decisions by users. Additionally, funding must be sustained in all of these areas to preserve the unbroken records that are vital to understanding the impacts of climate change.

Strategy 8: Preserve, Upgrade and Increase Monitoring, Data Analysis and Management

Uncertainty in the rate and magnitude of long-term climate change must be reduced. As one example, there are currently large gaps in the hydrologic observational network (e.g. rain and snow gauges) in the areas of California most vulnerable to climate change. Improved data analysis, and interpretation supported by a robust monitoring network can help identify trends, provide for better real-time system management, and evaluate and, if necessary, correct, adaptation strategies.

- For data to be useful in climate monitoring and climate change detection, there must be better and more consistent monitoring of critical variables such as temperature, precipitation, evapotranspiration, wind, snow level, vegetative cover, soil moisture and streamflow. Expanded monitoring is especially needed at high elevations and in wilderness areas to observe and track changes occurring in the rain/snow transition zone, which is critical for projecting future water supply.
- Similarly, improved observations of atmospheric conditions are needed to help define and better understand the mechanisms of the underlying atmospheric processes that lead to California's seasonal and geographic distribution of precipitation. This will help climate modelers to better project future rain and snow patterns on a regional scale.
- Information on water use is currently limited and often unreliable. Accurate measurement of water use can facilitate better water planning and management. By 2009, DWR, the state and regional Water Boards, the Department of Public Health, and the California Bay-Delta Authority will complete a feasibility study for a water use measurement database and reporting system.

Western Governors' Association

In 2006, the Western Governors' Association (WGA) released its report on Water Needs and Strategies for a Sustainable Future, which called for member states to take specified actions to incorporate consideration of climate change into state water management. That document was followed by a 2008 WGA Next Steps report which further detailed recommendations to "change for the better the way states and the federal government carry out their respective responsibilities regarding water management in the West."

For more information about the implementation of the reports' recommendations go to **www.westgov.org**.

Strategy 9: Plan for and Adapt to Sea Level Rise

Of the many impacts of climate change, sea level rise presents the most difficult planning challenge because of the great uncertainty around ice sheet dynamics, and the resulting range of consequences. In addition, sea level rise depends upon regional factors such as land movement (e.g. tectonic uplift) and atmospheric conditions. Much of the Sacramento-San Joaquin Delta consists of islands that are below sea level and protected by levees of varying stability. Rising sea levels increase pressure on fragile levees and pose a threat to water quality. Local and regional investments in coastal water and flood management infrastructure, as well as coastal and bay wetlands, beaches and parks, are also vulnerable to rising seas.

- The state will establish an interim range of sea level rise projections for short-term planning purposes for local, regional and statewide projects and activities.
- The Resources Agency, in coordination with DWR and other state agencies, should convene and support a scientific panel of the National Research Council (NRC) to provide expert guidance regarding long-range sea level rise estimates and their application to specific California planning issues.
- Based upon guidance from the NRC, DWR, in collaboration with other state agencies, will develop long-range sea level rise scenarios and response strategies to be included in the California Water Plan Update 2013.

PIER

In 2003, the California Energy Commission created the California Climate Change Center to implement the Commission's Public Interest Energy Research (PIER) Program long-term climate change research plan. The Center is a virtual research organization with core research at the Scripps Institute and complementary research at other scientific institutions in California.

Of particular interest to the water community are studies from the 2006 and upcoming 2008 Biennial Climate Science Reports required by Executive Order S-3-05, signed by Governor Schwarzenegger on June 1, 2005.

For more information go to **www.climatechange.ca.gov/research**.

Strategy 10: Identify and Fund Focused Climate Change Impacts and Adaptation Research and Analysis

Developing more focused research can help narrow the range of uncertainty in climate change, with a concentration on the vulnerability of water and other natural resources. This research will assist in planning for new projects, management activities and policies.

State Capitol, Sacramento

- In association with research institutions such as the Regional Integrated Sciences and Assessment centers, Lawrence Livermore and Berkeley National Laboratories, and the University of California, state agencies should identify focused research needs to provide guidance on activities to reduce California's vulnerability to climate change. The state should also explore partnerships with the federal government, other western states, and research institutions on climate change adaptation.

- Since some uncertainty will always exist, the state's water supply and flood management agencies need to perform sensitivity analyses of preliminary planning studies, and risk-based analyses for more advanced planning studies. As noted earlier, until better information becomes available, local agencies should plan for droughts 20 percent more severe than historic droughts. For flooding, sensitivity and risk-based analyses should consider an appropriate risk tolerance and planning horizon for each individual situation. Selection of climate change scenarios for these analyses can be guided by recommendations of the Governor's Climate Action Team.

- The state should sponsor science-based, watershed adaptation research pilot projects to address water management and ecosystem needs. Funding for pilot projects should only be granted in those regions that have adopted IRWM plans that meet DWR's plan standards and have broad stakeholder support.

- As part of the California Water Plan Update process, every five years DWR will provide revised estimates of changes to sea level, droughts, and flooding that can be expected over the following 25 years.

NEXT STEPS

CALIFORNIA WATER PLAN UPDATE 2009

California Water Plan Update 2009 builds upon Update 2005; a strategic plan for managing California's water that promotes Integrated Regional Water Management and improved statewide water management systems. The Update 2009 collaborative process has at its center a steering committee of 20 state agencies with jurisdictions over California water issues. The improved interagency coordination provides a robust statewide perspective and the inclusion of state companion plans helps inform an added emphasis on climate change, water quality, and integrated flood management. Update 2009 is specifically advised by a Climate Change Technical Advisory Group composed of scientists and engineers with climate change expertise.

Find out more at **www.waterplan.water.ca.gov**.

CALIFORNIA CLIMATE ADAPTATION STRATEGY

Building upon the recommendations and strategies set forth in this document, the California Resources Agency is coordinating the development of a statewide, cross-sector Climate Adaptation Strategy (CAS). The CAS will synthesize the most up-to-date information on expected climate change impacts to California, provide preliminary strategies to reduce the state's vulnerability to these impacts and develop plans for short and long-term actions.

For more information please go to **www.climatechange.ca.gov/adaptation**.

ACKNOWLEDGEMENTS

The Department of Water Resources wishes to thank the members of the following groups for the feedback they provided during the development of this document.

Climate Change Technical Advisory Group of the California Water Plan Update 2009

State Steering Committee of the California Water Plan Update 2009

California Resources Agency Climate Team

DWR's Climate Change Matrix Team

There are several foundational reports and processes that guide the development of climate change responses.

Intergovernmental Panel on Climate Change, Fourth Assessment Report (2007)

California Water Plan Update 2005 and the draft Update 2009, including Regional Water Quality Control Plans (Basin Plans), DWR and SWRCB

Proceedings of the Climate Change Research Needs Workshop, Western States Water Council (2007)

Public Interest Energy Research Program, California Energy Commission

Biennial Report, Governor's Climate Action Team (2006)

Progress on Incorporating Climate Change into Management of California's Water Resources, DWR (2006)

Draft FloodSAFE Strategic Plan, DWR (2008)

Draft Delta Vision Blue Ribbon Task Force Strategic Plan (2008)

Water Needs and Strategies for a Sustainable Future, Western Governors Association (2006)

CALIFORNIA DEPARTMENT OF WATER RESOURCES
1416 Ninth Street, Sacramento, CA 95814

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ATTACHMENT

NOT

PROVIDED

GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L03403, doi:10.1029/2010GL046442, 2011

Satellites measure recent rates of groundwater depletion in California's Central Valley

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[1] In highly-productive agricultural areas such as California's Central Valley, where groundwater often supplies the bulk of the water required for irrigation, quantifying rates of groundwater depletion remains a challenge owing to a lack of monitoring infrastructure and the absence of water use reporting requirements. Here we use 78 months (October, 2003–March, 2010) of data from the Gravity Recovery and Climate Experiment satellite mission to estimate water storage changes in California's Sacramento and San Joaquin River Basins. We find that the basins are losing water at a rate of 31.0 ± 2.7 mm yr^{-1} equivalent water height, equal to a volume of 30.9 km^3 for the study period, or nearly the capacity of Lake Mead, the largest reservoir in the United States. We use additional observations and hydrological model information to determine that the majority of these losses are due to groundwater depletion in the Central Valley. Our results show that the Central Valley lost 20.4 ± 3.9 mm yr^{-1} of groundwater during the 78-month period, or 20.3 km^3 in volume. Continued groundwater depletion at this rate may well be unsustainable, with potentially dire consequences for the economic and food security of the United States. **Citation:** Famiglietti, J. S., M. Lo, S. L. Ho, J. Bethune, K. J. Anderson, T. H. Syed, S. C. Swenson, C. R. de Linage, and M. Rodell (2011), Satellites measure recent rates of groundwater depletion in California's Central Valley, *Geophys. Res. Lett.*, *38*, L03403, doi:10.1029/2010GL046442.

1. Introduction

[2] Nearly 2 billion people rely on groundwater as a primary source of drinking water and for irrigated agriculture [*Alley et al.*, 2002]. However, in many regions of the world, groundwater resources are under stress due to a number of factors, including salinization, contamination and rapid depletion [*Wada et al.*, 2010]. When coupled with the pressures of changing climate and population growth, the stresses on groundwater supplies will only increase in the decades to come.

[3] In spite of its importance to freshwater supply, groundwater resources are often poorly monitored, so that a consistent picture of their availability is difficult and sometimes impossible to construct. Moreover, water withdrawals from pumping wells are often unrestricted and unmonitored, further complicating attempts to estimate rates of groundwater consumption. In short, no comprehensive framework for monitoring the world's groundwater resources currently exists.

[4] Satellite observations of time-variable gravity from the Gravity Recovery and Climate Experiment (GRACE) mission [*Tapley et al.*, 2004] may ultimately provide an important component of such a monitoring framework. Recent studies have clearly demonstrated that GRACE-derived estimates of variations of total water storage, TWS (all of the snow, ice, surface water, soil water and groundwater in region), when combined with auxiliary hydrological datasets, can provide groundwater storage change estimates of sufficient accuracy to benefit water management [*Yeh et al.*, 2006; *Zaitchik et al.*, 2008]. Most recently, the GRACE-based approach has been applied to estimate rates of groundwater depletion in northern India, a vast agricultural region that relies heavily on unmonitored groundwater withdrawals for its irrigation water supply [*Rodell et al.*, 2009; *Tiwari et al.*, 2009].

[5] In this study we use 78 months of GRACE data, from October, 2003 through March, 2010, to examine water storage changes in California's Sacramento and San Joaquin River Basins (~154,000 km^2) (Figure 1), which encompass the Central Valley (~52,000 km^2) and its underlying groundwater aquifer system. The Sacramento Basin and San Joaquin Basin, which includes the internally-draining Tulare Basin, are home to California's major mountain water source, the snowpack of the Sierra Nevada range. The Central Valley is the most productive agricultural region in the U. S., growing more than 250 different crops, or 8 percent of the food produced in the U. S. by value [*Faunt*, 2009]. It accounts for 1/6 of the country's irrigated land and supplies 1/5 of the demand for groundwater in the United States. As the second most pumped aquifer in the U. S. after the High Plains aquifer, the Central Valley offers a compelling example of the importance of groundwater as a resource, as well as the need to manage its use for sustained availability and productivity.

2. Data and Methods

[6] We use 78 months of GRACE gravity coefficients from Release-04 computed at the Center for Space Research at the University of Texas at Austin. The temporal mean was removed to compute gravity anomalies, and each field was

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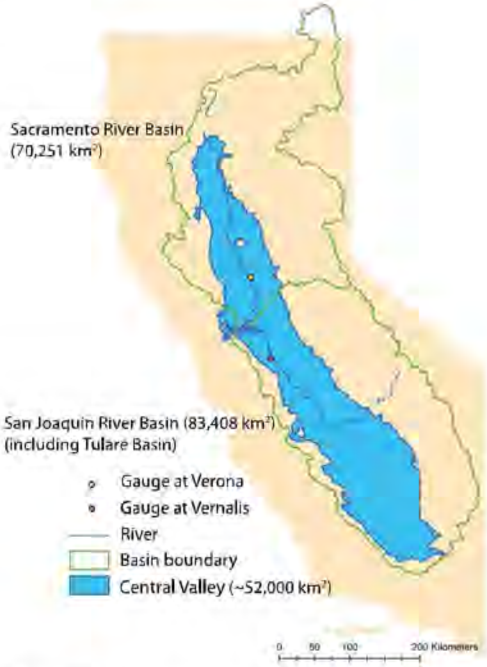


Figure 1. The Sacramento and San Joaquin river basins, including the Tulare basin and the Central Valley in California.

filtered to reduce noise [*Swenson and Wahr*, 2006] and then converted to mass in units of equivalent water height. We then used the method of averaging kernels [*Swenson and Wahr*, 2002] convolved with the GRACE coefficients to estimate the average water storage change for the combined Sacramento and San Joaquin River Basins. In order to restore power of the signal reduced by the truncation of the gravity coefficients (at degree and order 60) and filtering, the original estimate of GRACE TWS was scaled by a factor of 2.35 in order to recover an unbiased mass change estimate for the region [*Velicogna and Wahr*, 2006].

[7] Precipitation (P) data from the PRISM system [*Daly et al.*, 2008], satellite-based evapotranspiration (E) [*Tang et al.*, 2009] and U. S. Geological Survey (USGS) streamflow (Q) measurements at the Verona and Vernalis gauging stations (see Figure 1) were used in a water balance to assess the accuracy of the GRACE data (see Results).

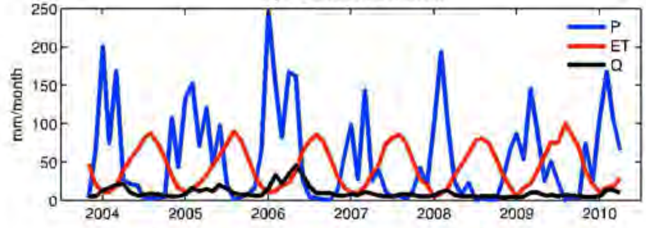
[8] Snow, surface water and soil moisture data were required to isolate the groundwater contribution to TWS changes. Snow water equivalent (SWE) data were obtained from the National Operational Hydrologic Remote Sensing Center, and were determined from a combination of remote, field survey and *in situ* observations assimilated into an operational snow simulation model [http://www.nohrsc.noaa.gov/technology/]. Surface water storage data were compiled for the 20 largest reservoirs in the river basins, which accounted for the bulk of the observed surface water changes, and were obtained from the California Department of Water Resources [http://cdec.water.ca.gov/reservoir.html]. Soil moisture content is largely unmeasured in the United States. Consequently, we estimated soil moisture storage using the average of three different soil moisture simulations [*Rodell et al.*, 2009] for the corresponding time period taken from land surface models [*Ek et al.*, 2003; *Koster and Suarez*, 1992; *Liang et al.*, 1994] included in the NASA Global Land Data Assimilation System [*Rodell et al.*, 2004a].

[9] GRACE TWS monthly errors are 45.3 mm, which is the sum of the leakage error [*Swenson and Wahr*, 2002] and the residual error in the filtered, scaled GRACE data. Since no published error estimates for the monthly surface water and SWE were available, we assumed an error of 15 percent of the mean absolute changes in each, i.e., 4.0 mm for surface water and 7.0 mm for snow. Soil moisture error was estimated as the mean monthly standard deviation of the three model time series, or 11.9 mm. These errors combine to yield a monthly error in our groundwater estimate of 47.5 mm. Uncertainties in the GRACE TWS, SWE, and surface water trends were estimated using a least squares fit, and then propagating errors from the monthly data using the covariance matrix. We find trend errors of 2.7 mm yr^{-1}, 0.4 mm yr^{-1}, and 0.2 mm yr^{-1} for GRACE TWS, SWE, and surface water respectively. Error in the soil moisture trend was computed as the standard deviation of trends from the three models, which is 2.8 mm yr^{-1}. The total error estimate for the groundwater trend, 3.9 mm yr^{-1}, combines these values and assumes that the individual errors are uncorrelated.

3. Results

[10] To assess the accuracy of our GRACE-derived water storage estimate for the combined river basins, we compared its time derivative, dS/dt, to that determined from an independent water balance for the region ($dS/dt = P - E - Q$). Figure 2a shows the monthly-averaged P, E, and Q data. Figure 2b shows that the observed water balance agrees well with the storage changes observed from GRACE, giving confidence that the GRACE data accurately capture the storage changes in the basins and can be used to estimate groundwater storage trends. The blue shading in Figure 2b represents the error in the GRACE dS/dt of 63 mm month^{-1}. The red shading represents the uncertainty in our water balance estimate of dS/dt, calculated after *Rodell et al.*

(a) Observed P, ET, and Q



(b) GRACE dS/dt vs Observed P−ET−Q

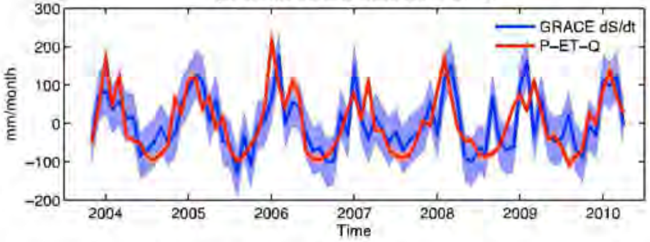


Figure 2. (a) Precipitation (P), evapotranspiration (E), and streamflow (Q) (mm/month) from October 2003–March 2010. (b) Comparison between observed total water storage change (dS/dt) and that from GRACE. Blue shading shows GRACE dS/dt errors. Red shading shows uncertainty in the observed water balance estimate of dS/dt.

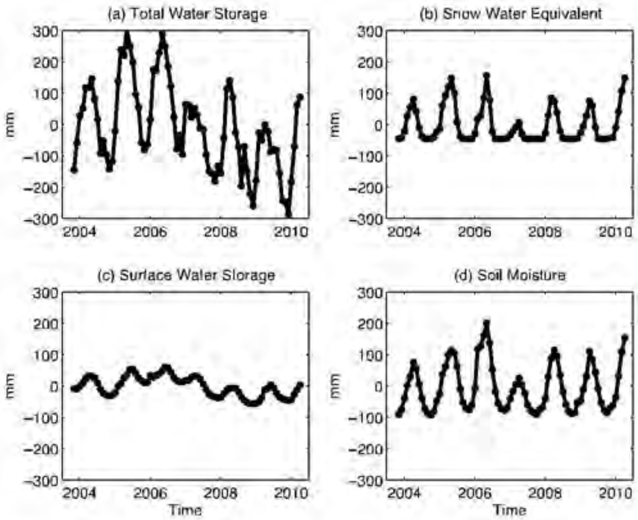


Figure 3. Monthly anomalies of (a) total water storage; (b) snow water equivalent; (c) surface water storage; and (d) soil moisture for the Sacramento and San Joaquin River Basins in mm from October 2003 to March 2010.

[2004a, 2004b] assuming relative errors of 15 percent in P [*Jeton et al.*, 2005] and E [*Tang et al.*, 2009], and 5 percent in Q [*Rodell et al.*, 2004b].

[11] Figure 3a shows the GRACE-based estimate of TWS variations for the combined Sacramento-San Joaquin Basins. The regional drought conditions, which persisted from 2006 through the end of the study, are evident. During the 78-month period beginning in October, 2003, total water storage declined at a rate of 31.0 ± 2.7 mm yr^{-1} equivalent water height, which corresponds to a total volume of 30.9 km^3 for the study period.

[12] In order to isolate groundwater storage variations from the GRACE TWS estimate, water mass variations in snow, surface water and soil moisture were estimated and subtracted from the total. Below-average SWE (Figure 3b) during the winters of 2006/07 through 2008/09 is apparent, consistent with the regional drought conditions, as are above-average conditions before and after that time period. These data show a slight decrease of 1.6 ± 0.4 mm yr^{-1} equivalent water height, which corresponds to 1.5 km^3 of water loss in 78 months. Figure 3c shows that surface water storage has been declining slightly since 2006. Over the length of the study period, surface water storage decreased at a rate of 8.8 ± 0.2 mm yr^{-1}, accounting for 8.7 km^3 of water loss. The loss of soil moisture (Figure 3d) was not significant during the study period. The trends for total water storage, SWE, surface water, soil moisture, and groundwater, along with the corresponding total volume changes for the October, 2003–March, 2010 period, are summarized in Table 1.

[13] Subtracting the snow, surface water and soil moisture components from GRACE TWS for the combined basins yields the groundwater storage variations shown in Figure 4. Over the course of the study period, groundwater storage decreased by 20.4 ± 3.9 mm yr^{-1}, which corresponds to a volume of 20.3 km^3 of water loss, or two-thirds of the total water storage loss in the river basins. We assume in this work that nearly all of the groundwater loss occurs in the Central Valley, and that the other major geological features in the combined basins, that is, the mountain ranges surrounding the Valley, have limited capacity to store groundwater. Based on separate water budget analyses of the Sacramento and San Joaquin basins (not shown) we estimate that over 80 percent of the 20.3 km^3 of groundwater loss occurred in the San Joaquin river basin, including the Tulare basin, which is consistent with a recent USGS report on groundwater availability in the Central Valley [*Faunt*, 2009]. The San Joaquin portion of the Valley has always relied on groundwater more heavily than its Sacramento counterpart because its drier climate results in more limited natural surface water availability.

Table 1. Trends in Water Storage for the Combined Sacramento-San Joaquin River Basins[a]

	Trend (mm yr^{-1})	Volume Lost (km^3)
Total Water Storage	−31.0 ± 2.7	30.9 ± 2.6
Snow Water Equivalent	−1.6 ± 0.4	1.5 ± 0.3
Surface Water Storage	−8.8 ± 0.2	8.7 ± 0.1
Soil Moisture	−0.2 ± 2.8	0.1 ± 2.7
Groundwater Storage	−20.4 ± 3.9	20.3 ± 3.8
Groundwater Storage (2003/10–2006/03)	−1.4 ± 12.7	0.5 ± 4.8
Groundwater Storage (2006/04–2010/03)	−38.9 ± 9.5	23.9 ± 5.8

[a] Trends and volumes are for October, 2003–March, 2010 unless otherwise noted.

[14] Figure 4 also shows a distinct break in the behavior of groundwater storage variations. Prior to the onset of drought conditions in 2006, there was no significant change in groundwater storage. However, beginning with the drought in 2006, a steep decline in groundwater storage of 38.9 ± 9.5 mm yr^{-1} (6.0 km^3 yr^{-1}) occurred between April, 2006 and March, 2010. Our estimate of the current depletion rate is nearly as large as previous model-based estimates of

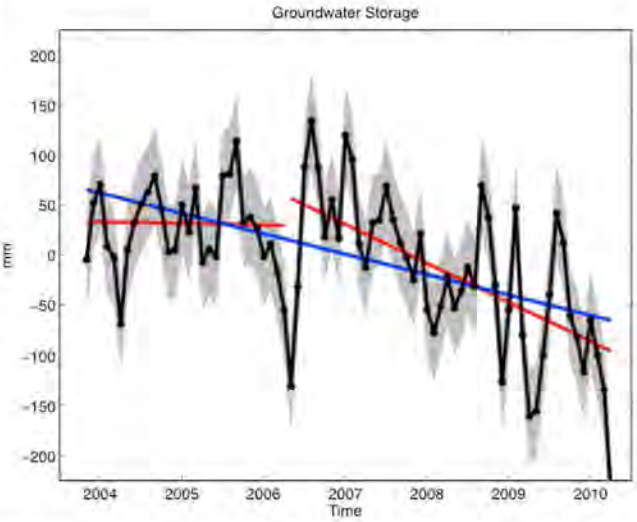


Figure 4. Monthly groundwater storage anomalies for the Sacramento and San Joaquin River Basins in mm, from October 2003 to March 2010. Monthly errors shown by gray shading. The blue line represents the overall trend in groundwater storage changes for the 78-month period. The red lines represent the trends from October 2003 and March 2006 and April 2006 through March 2010.

groundwater losses [*Faunt*, 2009] during the two major droughts of the last 50 years. Reported groundwater losses during those periods were approximately 12.3 km^3 yr^{-1} from 1974–76, and 8.2 km^3 yr^{-1} from 1985–89. Our estimated rate is also slightly larger than the loss of 4.9 km^3 yr^{-1} reported by *Faunt* [2009] for the more recent dry period between 1998 and 2003. Combining the USGS estimates of groundwater depletion between 1998 and 2003 with our GRACE-based estimates for October, 2003 through March, 2010 indicates that nearly 48.5 km^3 of groundwater has been lost from the Central Valley in the 12-year time period.

4. Discussion

[15] The picture that emerges from our GRACE based analysis is in agreement with *Faunt* [2009], and extends aspects of that study from its end date in 2003 to the present. Furthermore, results are consistent with the historical pattern of Central Valley agricultural water use. Facing significant cuts in managed surface water allocations during periods of drought, farmers, in particular those in the drier San Joaquin Valley, are forced to tap heavily into groundwater reserves to attempt to meet their irrigation water demands – this in a region where groundwater dependence is already high. Under these conditions, groundwater use rates exceed replenishment rates, and groundwater storage and the water table drop. Given the naturally low rates of groundwater recharge in the San Joaquin Valley, combined with projections of decreasing snowpack [*Cayan et al.*, 2006] and population growth, continued groundwater depletion at the rates estimated in this study may become the norm in the decades to come, and may well be unsustainable on those time scales.

[16] GRACE-based estimates of groundwater storage changes provide a holistic view of aquifer behavior that may not be otherwise possible, in particular in the developing world. Even in well-instrumented regions, a typical groundwater availability study is a massive undertaking, often several years in the making assembling supporting datasets and implementing numerical groundwater models. While there is no substitute for a dense network of ground-based observations and detailed groundwater model simulations, it is not clear that the major effort required for model-based studies can be sustained as part a routine monitoring program. Satellite gravimetry offers an important complement to both *in situ* observations and modeling studies by enabling independent estimates of groundwater storage changes, and by providing the opportunity to constrain aquifer-scale groundwater model simulations [*Zaitchik et al.*, 2008; *Lo et al.*, 2010].

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Water in the West Working Paper 1 | March 2011

Uncommon Innovation:

Developments in Groundwater Management Planning in California

By Rebecca Nelson

Woods Institute for the Environment | The Bill Lane Center for the American West
Stanford University

Uncommon Innovation:

Developments in Groundwater Management Planning in California

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Water in the West Working Paper 1

March 2011

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COVER IMAGES, CLOCKWISE FROM LEFT: DISCOVERY BAY DEVELOPMENT NEAR SAN JOAQUIN DELTA; DRY BED OF LEXINGTON RESERVOIR NEAR LOS GATOS, CA IN 2008; SWANS ON THE SACRAMENTO RIVER DELTA; HOOVER DAM ON THE COLORADO RIVER, NEVADA; WORKING IN MATADERO CREEK, PALO ALTO, CA **CREDITS:** SARA TOLLEFSON; CHRISTOPHER HYNES; INGRID TAYLAR; ANDREAS METZ; ALAN LAUNER

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GLOSSARY

DWR	Californian Department of Water Resources
GWMP	Groundwater Management Plan
UWMP	Urban Water Management Plan

EXECUTIVE SUMMARY

Unusually among western states in the United States, California has no statewide regulation of groundwater allocation or management. Rather, a complicated network of local agencies manages groundwater. The lack of state oversight means that there is little easily accessible information about how these agencies plan for the development and management of groundwater resources. We do know that significant areas of the State suffer from critical conditions of overdraft, where groundwater pumpers withdraw a far greater volume of groundwater than appears to be sustainable. These continually lowering water tables threaten serious economic, social, and environmental harms. Even so, groundwater use is increasing, and is projected to increase at a greater rate in the future.

Over decades, commentators have advocated reforming California's groundwater laws to alleviate problems of groundwater overdraft. Many suggestions derive useful inspiration from the experience of other States, and sometimes other countries. This report takes a different tack. It draws inspiration from how local agencies currently manage groundwater in California. It analyzes a collection of over 50 local groundwater management plans—most sourced directly from the agencies themselves—to find promising and innovative approaches to local groundwater management. These approaches are organized into four key themes: involving stakeholders, collecting good information, adopting a diverse "portfolio" of approaches to groundwater management, and taking steps to ensure that a plan can be implemented in practice.

Contrary to popular expectations, the report uncovers a treasure trove of innovative strategies for groundwater management in California. Among other things, we see agencies using measurable objectives for limiting groundwater drawdown; analyzing suites of management options with transparent decision criteria and simulations; collaborating with neighboring agencies; involving a broad range of agricultural, municipal, environmental, State, and federal stakeholders in their planning decisions; undertaking groundwater metering as well as monitoring; actively controlling pumping to limit groundwater drawdown; and protecting hydrologically connected surface waters and groundwater-dependent ecosystems. These practices may not be common, but they should be. This report is intended, in part, as a resource for local agencies, to enable these practices to become more widespread.

The home-grown innovations uncovered by this report point the way forward for local agencies to better manage groundwater in California, and the way towards an updated and improved State policy structure to encourage them to do so. Strengthening California's legislation for groundwater management planning, informed by current best practice, would provide a path towards better groundwater management and retain the State's historical focus on local agencies driving local change. The local planning actions uncovered by this report are not only innovative, they are also practical, down-to-earth and doable—they are being undertaken by different types of local agencies, with widely varying resources, across the State, right now.

PART ONE: INTRODUCTION

Unusually among western states in the United States, California has no statewide regulation of groundwater allocation or management. And although the State Water Resources Control Board has the legal power to prevent the "unreasonable use" of groundwater in the State and to control pumping by initiating adjudications of groundwater rights (Cal. Water Code §§ 2100-2102), it does not exercise that power (Sandino, 2005, p. 478). Instead, by convention, the state refrains from intervening and leaves these matters to local agencies, of which there are many different "species" established under different state statutes.

Commentators have advocated reforming California's groundwater laws over decades. Their suggestions have ranged from regulating groundwater at the State level (Hanak et al., 2010; Sax, 2003, p. 288; Taylor, 2010), to enforcing and improving prohibitions on wasting water generally (Neuman, 1998), to establishing a groundwater reserve as protection from drought (Langridge, 2009). Many suggestions derive useful inspiration from the experience of other States, and sometimes other countries. But in the short term, wholesale State-level water reform seems a distant prospect.

This report takes a different tack. It draws inspiration from how local agencies currently manage groundwater in California. Based on an analysis of a randomly selected collection of 52 groundwater management plans made by local agencies under Californian law (out of some 130 in total), this report highlights current "best practice" in local groundwater management planning in California. Here, best practice is defined by reference to accepted principles of water resources planning, like collecting adequate information, involving stakeholders, and pursuing multiple goals and strategies.

The innovations presented here are neither common nor representative of groundwater management in California—they are exceptional. Even putting the desirability of longer term reforms aside, these practices chart a path forward for local agencies in California in a way that is innovative, practical, down-to-earth and doable—a path that requires only that Californians look to each other for inspiration.

This report marks the start of a multi-year groundwater research program—part of the Joint Initiative on Water in the West, of the Woods Institute for the Environment and the Bill Lane Center for the American West at Stanford University. As a preliminary step, it does not seek to offer definitive solutions. Rather, it aims to challenge the common view of all groundwater management in California as lawless and backward, by highlighting innovative practice that can help chart a path to reforms which could grow organically from current practice. It also hopes to spur further empirical research on how groundwater management planning activities on paper translate to challenges and successes on the ground, by pointing to selected agencies and areas that show promise.

Part Two of this report sets out key practical and policy rationales for local water agencies to engage in groundwater management, with reference to the effects of overdraft. Part Three describes in more detail what is meant by "groundwater management planning" and presents a vision that defines "best practice" for the purposes of this report. Part Four sets the stage, outlining the roles of groundwater pumpers and local water agencies in managing groundwater in California, and how Californian law and policy provide for groundwater management plans. It suggests that this law and policy is now out of date and in need of reform, when compared to other legal developments in water planning in California. Part Five gives detailed examples of how selected local agencies in California approach groundwater management in an innovative and practical way. Part Six concludes and suggests how the innovations outlined in this report could lead to further policy developments in, and research on, Californian groundwater management.

PART TWO: WHY MANAGE GROUNDWATER?

To appreciate the need to manage groundwater, and the responsibilities that local agencies face in doing so, it is necessary to consider how groundwater is used and the consequences of depletion at the ground level. Californians use groundwater primarily for irrigation (around 75%) and municipal and domestic purposes (around 23%) (Kenny & U.S. Geological Survey, 2009, p. 7). Groundwater use is increasing, and is projected to increase at a greater rate as climate change threatens the reliability of surface water supplies (Cal. Dep't of Water Resources, 2008, p. 5).

Even at current rates of use, in some regions of California, groundwater pumpers withdraw a far greater volume of groundwater than appears to be sustainable. The latest state assessment of critical groundwater overdraft in California dates from 1980. It found that 11 basins suffered from "critical conditions of overdraft", meaning that "continu[ing] present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts"—terms which are defined at the local level (Cal. Dep't of Water Resources, 2003, p. 98).

Economically, water production costs may increase because diminishing groundwater levels mean that more energy is needed to pump water to the surface. It also costs more to treat groundwater that has been affected by quality problems associated with overdraft, such as intruding seawater, saline groundwater, or newly mobilized contaminants (Zekster, et al., 2005, pp. 402-403). At the extreme, impaired quality can render groundwater unusable (Cal. Dep't of Water Resources, 2003, p. 8), and possibly without economic value. Groundwater extraction has caused groundwater levels to decrease by more than 200 feet in some parts of California (U.S. Geological Survey, 2003, p. 3), and ground subsidence affects over half of the San Joaquin Valley (Zekster, et al., 2005, p. 401). This permanently reduces the storage capacity of the aquifer and may damage overlying infrastructure and aggravate seawater intrusion. In some areas, subsidence has resulted in the need for costly flood control infrastructure (Santa Clara Valley Water Dist., 2001, pp. 13, 44).

Intensive groundwater use also represents a powerful potential source of social conflict, although it has certainly provided significant social benefits from economic development (Llamas & Martinez-Santos, 2005). Though there appears to be little sustained work on the social effects of overdraft in California, the economic harms described above naturally have corresponding social effects.

In ecological terms, groundwater depletion may adversely affect connected streams, lakes, wetlands, springs, coastal environments, and the flora and fauna which depend on aquifers directly, or on these connected systems (Alley, et al., 1999, pp. 30-44). The ecological impacts of groundwater overdraft in California include diminished streamflow and lake levels, damaged vegetation, and corresponding effects on fish and migratory birds. Effects are felt at Lake Merced near San Francisco, Redwood Creek in northern California, the Cosumnes River near Sacramento, and the Owens River Valley, to name a few (Zekster, et al., 2005, pp. 398-401).

Groundwater management planning is a key way to prevent and holistically deal with these effects on a vital water supply for farms and cities in California.

PART THREE: GROUNDWATER MANAGEMENT PLANNING

Historically, water resource problems were considered "technical challenges to be resolved through purely technical means" (Feldman, 1991, pp. 72-73). A more modern view of water resources management conceives of a much more comprehensive, planning-based approach to water management. Such an approach involves managing all water sources, involving stakeholders, meeting the basic needs of both human water users and the environment, and managing demand through greater efficiency, public education, and incentives to conserve water—in addition to simply augmenting water supplies (Brooks, et al., 2009; Palaniappan & Gleick, 2009, p. 13). This report adopts this holistic understanding of groundwater management and draws out elements of California's local agency plans that together, build such an approach. Before discussing these local approaches in detail, it is appropriate to consider in greater depth what each element of this holistic vision of groundwater management planning requires.

1. Overview of water resources planning

Water resources planning refers to a process of (Gardner, et al., 2009, p. 273; Gleick, 1998):

- systematically gathering information about a water resource, including its status and its environmental, social and economic values;
- identifying existing rights and interests;
- evaluating present and future water needs;
- setting guidelines for future management;
- regularly reviewing the plan to ensure it can adapt to changing circumstances; and
- publicly reporting on the plan's implementation.

Water planning is particularly important as a way to formally anticipate and deal with variable water availability in arid and semi-arid areas, and as groundwater extraction and resource stress intensify. Although some jurisdictions use water plans as a primary way to control access to groundwater, in California, management plans for groundwater overlay allocation systems founded on common law rights. Groundwater management plans are one type of water management plan among many, including:

- the five-yearly State Water Plan, which sets out goals and objectives (Cal. Water Code § 10004);
- integrated water resources management plans (Cal. Water Code §§ 10530-10550);
- urban water management plans (Cal. Water Code §§ 10610-10656); and
- agricultural water conservation programs (Cal. Water Code §§ 10520-10523).

Whether or not they have legal force, plans are "the basic instrument for ensuring the rational management of the water resources available" (Caponera, 2007, p. 137; Sax, 2003, p. 317).

2. Involving stakeholders

Public participation has been a feature of water planning in the United States for decades, though its implementation has not always been uncontroversial (Wengert, 1971). The two key issues are who to consult, and what role they should play. It is increasingly recognized that in water matters, "everyone is a stakeholder", including disadvantaged groups, individuals, non-government entities, and local groups of all kinds (Global Water Partnership Technical Advisory Comm., 2000, pp. 15-17; Iza & Stein, 2009, p. 86). Stakeholders should make "significant contributions to outcomes", rather than merely "legitimize decisions already made" (Bergkamp, et al., 2009, p. 39; Global Water Partnership Technical Advisory Comm., 2000, pp. 15-17). For example, in the groundwater sphere, stakeholders should be involved in "decid[ing] the specific conditions under which the undesirable consequences [of groundwater depletion] can no longer be tolerated" (Alley, et al., 1999, p. 76). Formal advisory committees of stakeholders assist local water agencies by providing a variety of perspectives, reducing future conflicts, achieving local buy-in, and broadening the discussion beyond purely operational issues (City of San Diego Water Dep't, 2007, pp. 3-18).

3. Collecting information

Pumping groundwater without monitoring extraction or the state of the aquifer has been compared to a business continually withdrawing money from a bank account without any bookkeeping system (U.S. Geological Survey, 2003, p. 4). Indeed, the Californian Legislature itself acknowledges that information about groundwater is required to properly manage the resource (Cal. Water Code § 10750(b)). The most fundamental data for groundwater management relates to groundwater levels, quality, extraction (Taylor & Alley, 2001, p. 1), and the health of dependent ecosystems. When local agencies require well owners to register and meter their wells, and report groundwater extraction, they gain crucial information about the stress on the resource and the wider local impacts of depletion, for example, ground subsidence. When they also collect ecological information—information that may initially seem outside their "mission"—they gain the ability to manage the resource for broader and longer-term sustainability, beyond a narrow focus on short-term water supply goals.

4. Adopting a portfolio approach to groundwater management strategies

A portfolio approach to groundwater management, as presented here, has two key characteristics—it involves multiple goals, and it involves using multiple strategies to pursue each goal. Traditionally, local water agencies in California focus on a narrow portfolio of goals. They focus very strongly on groundwater supply for consumptive purposes, often to the exclusion of other goals, like maintaining or restoring ecosystems, protecting connected surface waters, or ensuring that groundwater use minimizes third-party impacts on society.

Historically, California has also preferred engineering solutions to water problems over other approaches, and to some extent, this remains true, unnecessarily impoverishing California's portfolio of water management strategies (Hanak, et al., 2010, p. 25). Rather than seeking a "silver bullet", water problems are better approached with a portfolio of strategies (Hanak, et al., 2010, p. 34). Although the local context will determine which strategies are likely to be effective, empirical evidence suggests that having a larger and more diverse suite of water management actions is likely to enhance overall effectiveness and robustness; redundancy can encourage greater compliance because different users will respond to different approaches and increase "complementarity", whereby different approaches reinforce each other (Cash, 2006, p. 285).

Water resources literature is filled with different methods of dealing with managing groundwater to control depletion. Given the historical emphasis on engineered, supply-side solutions, this report focuses on how local Californian agencies manage groundwater demand using voluntary and mandatory measures; infrastructure measures are covered to a lesser degree, with an emphasis on the conjunctive management context, as described below.

A mandatory approach to demand management involves limiting extraction to a target level by mandating reductions in existing pumping, limiting the construction of new wells, or requiring conservation measures. Ideally, the target extraction level should avoid irremediable impacts on immediate and downstream freshwater ecosystems and maintain their integrity; consider links with water quality; and include "measures aimed at coping with droughts", such as a drought reserve, given that groundwater is often required as a buffer against drought (Dellapenna, 2004, pp. 89, 90; Flint, 2004, pp. 41, 47; Nevill, 2009, p. 2627). Since mandatory measures often encounter strong opposition from existing and aspiring rights-holders; limits should be set well before extraction approaches those levels (Nevill, 2009, p. 2628).

A voluntary approach to demand management entails using fees, educational measures or water efficiency projects to reduce groundwater pumping. The fee-based approach entails charging private well owners fees for groundwater extraction. In theory, the economic value of water comprises both its market value and its "non-market values to human capital and ecosystem service values" (Lant, 2007, p. 64). In practice, realizing this vision through fees is difficult—it is far easier to leave out or under-account for costs that are difficult to calculate, like the costs of "servicing the regulatory framework, environmental degradation, forced social change, impacts on future generations and this generation in the future" (Connell, 2007, p. 31). One method of introducing fees while reducing resistance and encouraging conservation is to use tiered charges, or allow users to pump a certain volume free of charge (Schiffler, 1998, p. 171).

Infrastructure measures entail either constructing or changing the operation of existing infrastructure. Infrastructure measures include reducing demand for local groundwater by treating and recycling wastewater or importing water from other basins. However, it must be noted that relying heavily on imported surface water may be ecologically damaging to the source area (Langridge, 2009, pp. 317-318). Another infrastructure-related measure is conjunctive management—using surface water and groundwater in a coordinated way, such that surface water is used to recharge groundwater when surface supplies are abundant, and groundwater is used preferentially ("recovered") in times of shortage. This can involve directly replenishing aquifers using spreading basins, injection wells or riverbeds. While this has obvious advantages, recovering groundwater from storage during a severe drought can compromise connected surface water systems and cause all of the problems of severe overdraft discussed above (Langridge, 2009, pp. 317-318). Alternative solutions include changing the spatial or temporal management of pumping to reduce the intensity of local depletion effects (Alley, et al., 1999, pp. 72-73).

This Part has presented a theoretical vision of holistic groundwater management planning. With this vision in mind, Part Four now examines the law and policy of groundwater management planning in California, before Part Five discusses Californian groundwater management planning in practice.

PART FOUR: GROUNDWATER PUMPERS, WATER AGENCIES, AND THE LAW AND POLICY OF GROUNDWATER MANAGEMENT PLANNING IN CALIFORNIA

Before discussing how Californian law provides for groundwater management plans, this report first sets the stage by presenting answers to two vital preliminary questions. What role do groundwater users have in controlling groundwater? And which local water agencies have an interest in managing groundwater?

1. What role do groundwater pumpers have in managing groundwater?

In most areas, well owners can pump groundwater without holding any administrative permit (Sax, 2003, p. 270). The common law doctrine of correlative rights regulates the taking and use of groundwater, unless local arrangements apply. That doctrine limits groundwater pumping to the "safe yield", being the volume of natural and artificial recharge of the aquifer, which is shared by overlying landowners on an "equitable basis" (regardless of their particular uses), and by non-overlying landowners, if there is sufficient water available (Katz v. Walkinshaw, 74 P. 766 (Cal. 1903)).

These common law rules have been heavily criticized as insufficient to properly manage groundwater or control groundwater depletion (Sandino, 2005, p. 479). To limit extraction, they require an individual user to file a lawsuit to settle all the groundwater rights in a basin, a course of action which is expensive and time-consuming (Langridge, 2009), and one which most agencies are very eager to avoid. As a result it is rarely done: adjudications cover only 22 of California's 431 basins (Cal. Dep't of Water Resources, 2003, p. 106; 2009). Without basin adjudications, "users can continue their use unabated", and the system may even encourage overpumping (Krieger & Banks, 1962, pp. 61-62; Sandino, 2005, p. 477). Adjudications are also limited thematically, since they cannot regulate groundwater pumping to protect water quality (Cal. Dep't of Water Resources, 2003, p. 40), nor plan for future changes in supply. Finally, some view resolving water disputes adversarially, rather than collaboratively, as inherently "dysfunctional", a process that "hinders our ability to create win-win outcomes" (Sheer, 2010, pp. 3, 4).

Groundwater management plans can help to address some of the problems with this common law system. In contrast to basin adjudications, groundwater management plans can cover large areas, and can integrate considerations of water quantity and quality, all with an eye to the future. Nonetheless, even with California's system of voluntary groundwater management plans, if local water agencies do not act, groundwater pumpers have complete management control over the resource, with no higher level of cooperation or rational planning.

2. Which local water agencies have an interest in managing groundwater?

California's Water Code provides for an astounding array of over 20 general types of local water agencies, which may be established anywhere in the State (Cal. Dep't of Water Resources, 2003, p.34, Table 32). On the ground, there are around 2300 of these agencies,[2] which may have interests in groundwater. These agencies may supply groundwater to their customers, or supply surface water to customers who also use groundwater, or they may wish to protect the resource because they plan to use it as a source of supply in the future. Such agencies include California water districts, county water

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[2] This number was arrived at by taking the 20 statutes, which the current State Groundwater Bulletin indicates may have groundwater management powers, and noting the number of agencies which fall into these types, as set out in the California Controller's latest report on special districts (Cal. Dep't of Water Resources, 2003, p. 34; Cal. State Controller, 2010, p. 1061).

districts, irrigation districts, reclamation districts, water conservation districts, water replenishment districts, water storage districts, and waterworks districts.

In addition to these general types of agencies, several State acts target specific geographical areas suffering from local groundwater problems by creating special districts with powers tailored to dealing with these problems. Their powers include controlling in-basin pumping in situations of actual or threatened overdraft, limiting exports, spacing wells to minimize well interference, and imposing groundwater-related charges. Some view these districts as "the state-of-the-art in local groundwater management . . . successful in addressing their groundwater problems, and [] useful models to be considered for use in other parts of the state", while conceding that State-level political will may be insufficient to extend this technique to other overdrafted basins (Sandino, 2005, p. 484). Indeed, sometimes a local water agency is created in the form of a general statutory district (not a special district) to deal with serious groundwater depletion problems, possibly giving force to this view (Turlock Groundwater Basin Assoc., 2008, pp. 33-34). The DWR lacks an oversight function in relation to water management by both local water agencies and also special districts (Cal. Dep't of Water Resources, 2003, p. 33).

As these complicated agency arrangements suggest, a vast range of local agencies has an interest in managing groundwater. This includes many general statutory types of agencies which have varying interests in managing groundwater—as an existing or potential future user, or as a supplier of surface water to customers who also use groundwater. It also includes specially created districts which were established to deal with serious local groundwater problems.

3. How do Californian law and policy provide for groundwater management plans?

In California, statutory arrangements for groundwater management plans overlay the common law allocation system, and allow agencies to manage groundwater more proactively than is possible under common law rules (Hanak, 2003, p. 108; Sandino, 2005, p. 484).

California's Groundwater Management Act (AB 3030) encourages local-level groundwater management in basins with significant water use, which are not adjudicated (Cal. Water Code §§ 10750(a), 10750.2, 10752(b)). It permits a local agency, which includes a special district or a group of agencies, to adopt and implement a groundwater management plan (GWMP) for all or part of the agency's service area (Cal. Water Code §§ 10752(g), 10753(a), 10755.2).

Adopting a GWMP involves formal procedural steps, including making specific resolutions, issuing public notices and conducting public hearings (Cal. Water Code §§ 10753.2-10753.6). If landowners representing more than 50 percent of the assessed value of the land within the local agency protest against the GWMP, the local agency may not adopt it (Cal. Water Code § 10753.6). A GWMP may cover 12 enumerated matters. The quantity-related matters are: mitigating conditions of overdraft, replenishing extracted groundwater, monitoring groundwater, facilitating conjunctive use operations, and constructing and operating groundwater recharge, conservation, water recycling, and extraction projects (Cal. Water Code § 10753.8). An agency "shall adopt rules and regulations to implement and enforce" a GWMP (Cal. Water Code § 10753.9(a)).

When a local agency adopts a GWMP, it gains power to manage groundwater that may go beyond its powers under its establishing legislation. First, it may limit or suspend groundwater extractions, provided it "has determined through study and investigation that groundwater replenishment programs or other alternative sources of water supply have proved insufficient or infeasible to lessen the demand for groundwater" (Cal. Water Code § 10753.9). In this context, it is important to note that pumping limits need not amount to a constitutional taking, since groundwater pumpers are restricted to pumping for a reasonable beneficial use (Allegretti & Co. v. County of Imperial, 42 Cal. Rptr. 3d 122 (Cal. App. 2006)). Second, a local agency may impose charges for groundwater extraction or replenishment on the endorsement of a majority of voters (Cal. Water Code § 10754.3). On the other hand, failing to adopt a GWMP makes a water agency ineligible to receive water grants and loans from the state (Cal. Water Code § 10753.7(b)).

Californian law for GWMPs fills the void of comprehensive management that common law rules create, granting California's complicated web of local water agencies powers to plan and manage local groundwater proactively. But it is now out of date, and does not match up to modern principles of groundwater planning. It emphasizes augmenting supply to the exclusion of managing demand, and does not require local agencies to take any sort of action, even in cases of severe overdraft (Cooley, et al., 2009, p. 11; Hanak, 2003, pp. 107-108). While procedures are set out for amending a GWMP, a local agency is not *required* to review its GWMP, keep it up-to-date, or even implement it. Indeed, agencies have sometimes adopted GWMPs as a strategy to head off state intervention, without a strong intention to implement them (Hanak, 2003, p. 107).

Almost twenty years of groundwater management planning in California (since 1992) have seen policy on the subject mature. Early GWMPs focused on preventing the export of groundwater from local areas rather than on comprehensive management, and did not focus strongly on implementation (Cal. Dep't of Water Resources, 2003, p. 54). The Legislature responded by requiring greater rigor, directing the DWR to develop criteria for evaluating GWMPs, and requiring a local agency to prepare a GWMP that met certain requirements in order to be eligible for public funds for groundwater projects (Cal. Dep't of Water Resources, 2003, p. 54).

There are five broad types of information that local agencies preparing GWMPs either *must* include to meet the funding criteria, or *should* include, according to the DWR (Cal. Dep't of Water Resources, 2003, pp. 54-62):

- **Context**: a description of the area to be managed under the plan, and a map showing the basin, the agency's service area, and surrounding agencies;

- **Public and agency involvement**: a plan to involve other local agencies with overlapping service areas; a description of current or planned actions to coordinate with agencies that have powers over land use and surface zoning; a statement that the public was informed of how they could participate in developing the GWMP; and an advisory committee of interested parties to help develop and implement the plan;

- **Basin management objectives** and links between these objectives and the goals and actions of the plan;

- **Monitoring**: components related to monitoring and managing groundwater levels and quality, subsidence, and changes in surface flow and surface water quality that directly affect groundwater levels or quality, or are caused by pumping; monitoring protocols for the purpose of measuring against the basin management objectives; and a detailed description of the monitoring plan, including elements that relate to the type of monitoring, the type of measures, and the frequency and locations of monitoring;

- **Accountability and review**: a commitment to produce periodic reports that cover implementation of monitoring, management actions, the success or otherwise of management actions in meeting objectives, proposed management actions, and any plan changes; and a commitment to periodically re-evaluate the entire plan.

While DWR's official groundwater bulletin sets out a small number of examples in relation to some of these elements, it provides little guidance on innovative planning approaches or best practice (Cal. Dep't of Water Resources, 2003, pp. 54-62). Nonetheless, GWMPs have reached significant milestones, sometimes the result of truly impressive multi-year collaborations between multiple agencies and scores of stakeholders (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 4; Sacramento County Water Agency, 2006, p. 1-8; Sonoma County Water Agency, 2007, p. 1-6).

Recognizing that there is currently very little information available on sophisticated groundwater management planning efforts across California, and that water planning principles in California have moved beyond DWR's recommendations of 2003, the next section describes elements of current local GWMPs which capably address broader issues in groundwater management.

Stepping back from GWMPs, water planning practice more generally has become much more sophisticated both inside and outside California since the GWMP provisions were last amended. Rigorous legislative requirements, developed between 2002 and 2009, now apply to urban water management plans (UWMPs). These requirements demonstrate that best practice water planning in California now involves higher expectations than local agencies are asked to meet under the elements that are required or recommended for GWMPs.

Under the UWMP legislation, large water suppliers *must* adopt UWMPs, including for groundwater sources, regardless of whether they are seeking grants from the State (Cal. Water Code §§ 10610-10656). UWMPs must include:

- **Greater analysis of the planning context** through an evaluation of climate-related risks, and by considering environmental, social, and technological factors (Cal. Water Code § 10631(c), (g)(1));
- **More extensive public involvement**, namely involving disadvantaged groups in the planning process (Cal. Water Code § 10642);
- **A focus on managing demand in addition to enhancing supply**, including methods for evaluating the effectiveness of demand management measures, prohibiting wasteful uses during water shortages and imposing penalties for excessive use (Cal. Water Code §§ 10615, 10620(f)); and
- **More rigorous requirements for accountability and review**—requirements to review and update UWMPs every five years and to *implement* the UWMP or become ineligible for water management grants or loans from state water agencies (Cal. Water Code §§ 10621(a), 10631.5, 10640). UWMPs are also required to be much more accessible, transparent, and subject to accountability requirements than GWMPs. UWMPs must be submitted to the DWR, the California State Library, and "any city or county within which the supplier provides water supplies within 30 days after adoption" (Cal. Water Code § 10644(a)). DWR must also submit a report on the status of UWMPs and data on their effectiveness to the Legislature (Cal. Water Code § 10644(b)). None of this is true of GWMP plans.

Water planning law and policy have undoubtedly moved beyond the current requirements and policy recommendations in relation to GWMPs. In response, Part Six suggests reforms, inspired by the vision of groundwater planning presented in Part Three, the newer provisions for UWMPs discussed here, and the innovations in GWMPs now presented in Part Five.

PART FIVE: INNOVATIONS IN GROUNDWATER MANAGEMENT PLANNING IN CALIFORNIA

California's local water agencies have significant powers to plan and manage their local groundwater resources. But they are not subject to any legal mandates to do so, and they may come under significant pressure from local groundwater users to refrain from curbing local use or imposing additional responsibilities (Mendocino City Community Services Dist., 1990 (as amended, 2007), p. 39).

Despite these pressures, some local water agencies in California develop and implement innovative approaches to groundwater management. But few know about them. Not only is there very little academic or policy literature on GWMPs in California, but there is no comprehensive State-wide database of digital GWMPs, and information barriers sometimes prevent even neighboring agencies from finding out about planning activities. GWMPs themselves refer to the "independent character" of local water agencies creating fragmented governance and management, and to the difficulty of sharing control, building trust, and resolving inter-agency differences (GEI Consultants, 2009, p. 60; Kings River Conservation Dist., 2005, p. 5-1; N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 98). Others also recognize that acting independently, local agencies "have found it difficult to wield the political and financial power necessary to mitigate conditions of groundwater overdraft" (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 20).

Acknowledging these substantial pressures, and the present lack of any widely available analysis of local groundwater management planning efforts, the body of this report describes elements of current local GWMPs that address key issues in groundwater management, and give substance to the theoretical vision of holistic groundwater management planning presented in Part Three. Where possible, examples of different statutory types of entities (for example a county government vs. a water district vs. an irrigation district) or entities in different circumstances (a large vs. a small irrigation district) are given for each issue. As the examples show, elements of best practice planning are found in the actions of small agencies with very limited resources, as well as in large agencies; in the actions of general water districts as well as special districts dedicated to groundwater management; and in the elements of older as well as more recent GWMPs.

While each solution may not be universally feasible or legally possible, it is hoped that local agencies around California will consider the approaches described here in formulating their own groundwater management actions, recognizing that management innovation is not necessarily precluded by scarce resources, or any particular statutory form.

It is important to emphasize that this Part discusses examples of single innovative practices in groundwater planning. It does not evaluate each GWMP as a whole, but rather, suggests that the particular element found in that GWMP, together with other elements suggested here, would constitute innovative practice. This Part also does not suggest that the elements of GWMPs given here are the only examples of these elements, or that they are the best that GWMPs can be; indeed, there are elements of best practice described in the foregoing sections that do not appear in any of the GWMPs reviewed for this report.

This Part largely takes the form of tables which collate elements of agencies' GWMPs, in the following categories:

- **Planning for action**: elements that help to ensure that GWMPs may successfully be implemented, independent of their content;
    - Table 1: Examples of governance structures for implementing GWMPs, listed in increasing levels of formality;

  - Table 2: Determining goals and assessing and reporting performance;

- **Cooperation and stakeholder participation**: elements for meaningfully using stakeholder collaboration to pursue the goals of a GWMP:
  - Table 3: Subjects of collaboration between water agencies in GWMPs;
  - Table 4: Structures for involving stakeholders in GWMPs;
  - Table 5: Avoiding and resolving disputes when formulating and implementing GWMPs;

- **Collecting information about the groundwater context**: ensuring informed planning by collecting information on groundwater and its context:
  - Table 6: Gathering and standardizing information on groundwater status and use;

- **A portfolio approach to groundwater management planning**: embracing multiple goals and multiple strategies for achieving GWMP goals:
  - Table 8: Methods of managing groundwater demand;
  - Table 9: Methods of using different water sources conjunctively;
  - Table 10: Methods of protecting and enhancing recharge and examples of water banking;
  - Table 11: Methods of protecting connected surface waters;
  - Table 12: Methods of restoring ecosystems and minimizing ecological impacts; and
  - Table 13: Methods of considering economic and financial sustainability.

References to groundwater basins and agencies appear in bold.

1. Moving beyond words: Planning for action

As Part Four described, many early GWMPs did not focus strongly on implementation—so much so that the Legislature took action to require them to be more rigorous. Nonetheless, it stopped short of requiring an agency to *implement* its GWMP, as is the case for UWMPs. Regardless of legal requirements, foremost among the desirable characteristics of a GWMP are that it should be able to be implemented, and it should be possible to determine whether it is working with reference to goals.

Choosing an appropriate governance structure is an important part of ensuring that a GWMP can be implemented. Various governance structures are used to implement GWMPs, at varying levels of formality (Table 1). Considerations relevant to deciding on a governance structure include: the powers necessary to implement the plan; how stakeholders will be represented; how other interest groups can participate; how the group will coordinate with basin neighbors; how it will be funded; and whether an independent coordinating group will construct projects, rather than individual members (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 98).

Table 1: Examples of governance structures for implementing GWMPs, listed in increasing levels of formality

Loose group based on MOUs	The **Stanislaus and Tuolumne Rivers Groundwater Basin Association** is a loosely bound group of entities, organized around a memorandum of understanding which aims to promote coordination of groundwater management planning activities (Stanislaus & Tuolumne Rivers Groundwater Basin Assoc., 2005, App. A). Similarly, a series of MOUs links the **Kaweah Delta Water Conservation**

	District and, as of 2007, each of 16 stakeholder entities (Kaweah Delta Water Conservation Dist., 2006, pp. 50-51; 2008, p. 19).
Non-profit corporation	Local water and land management agencies may become voluntary members of a non-profit corporation, to which they pay dues. This form of group is not a new agency, but operates by consensus for the mutual benefit of its member agencies. The **Water Resources Association of San Benito County** is one such group. Its purposes include to "refine, select, and coordinate implementation of management actions" set out in the GWMP, deal with proposals for water banking and transfers, and communicate with the public (Jones & Stokes Assoc., 1998, p. 67; http://wrasbc.isoars.com/index.html).
Joint powers authority	A joint powers authority (JPA) is formed by two or more public agencies. Such an entity is a separate legal entity which can, for example, issue bonds, employ staff, and construct, operate and maintain facilities. JPAs themselves can prepare, adopt, and implement GWMPs. Examples of such entities, which have adopted and implemented GWMPs, are the **Soquel-Aptos Area Groundwater Management Committee**, the **Chowchilla Water District-Red Top Resource Conservation District** JPA, the **Sacramento Central Groundwater Authority**, and the **Tulare Lake Bed Groundwater Basin** JPA (Angiola Water Dist. et al., 1999, p. 1; Chowchilla Water Dist.-Red Top Resource Conservation Dist. Joint Powers Auth., 1997; Sacramento Cent. Groundwater Auth., 2009, p. 1; Soquel Creek Water Dist. & Cent. Water Dist., 2007, p. 1).

As a result of legislative amendments in 2002, Californian GWMPs are now required to include basin management objectives (BMOs) to identify issues and goals for the plan area. Regardless of the precise nature of groundwater management objectives (see section 5.4 for a discussion of their content), they should have specific criteria that make it possible to determine whether they are being achieved, and they should trigger management actions if they are not achieved (Table 2). Agencies may choose between the many management options available to them by running performance simulations and using decision criteria that are keyed to their BMOs. Agencies can also demonstrate their commitment to implementing a GWMP and increase their accountability by including a plan of prioritized actions with a timeline and reporting structure.

Table 2: Determining goals and assessing and reporting performance

Using measurable objectives	The objectives of the GWMP for **Central Sacramento County** include: • Maintaining the long-term average groundwater extraction rate at or below 273,000 af/yr, a level which was agreed to avoid undue risk "to private and public well owners by dewatering wells, degrading water quality, creating ground subsidence, and adding cost to pumping groundwater from lower elevations". The GWMP provides a full definition of "long-term average" and supporting material on the modeling process used to develop the limit (Sacramento County Water Agency, 2006, pp. 2-29, 3-22). • Maintaining groundwater elevations within all areas of the basin within

specific operating ranges. A five-square-mile grid is used to define and report on this objective (Sacramento County Water Agency, 2006, pp. 3-2 to 3-3).

The **Eastern San Joaquin Groundwater Basin** GWMP envisions setting "basin operations criteria", being "quantitative target groundwater levels and descriptive basin condition levels". The primary uses of these targets would be judging the effectiveness of groundwater recharge and controlling groundwater exports (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 147).

Using triggers for management action

Each objective of the **Central Sacramento** GWMP has four defined "trigger points", at which the basin governance body will consider taking specified actions, in response to conditions not meeting the objective. These actions include: investigating the cause of the condition, reducing pumping to comply with the objective, and imposing a monetary assessment against well owners who continue to pump at high levels in areas that do not comply with the objective (Sacramento County Water Agency, 2006, p. 4-3).

Similarly, the **Ojai Basin Groundwater Management Agency** plans to establish "action levels" for groundwater elevations and stream flow, at which it will take special action to protect groundwater supplies in the basin. These will be implemented, in part, through ordinances dealing with conservation measures (Ojai Basin Groundwater Mgmt. Agency, 2007, p. 9).

Analyzing management options with decision criteria and simulations

The **San Benito** GWMP applies explicit selection criteria to compare and select management options. Options are favored if they meet multiple objectives, do not adversely affect any objective, are cost-effective, equitable, maintain management flexibility, involve relatively little administrative effort, have few permitting requirements and raise few legal issues, and are likely to win public acceptance (Jones & Stokes Assoc., 1998, pp. 44-45).

Borrego Water District's GWMP transparently evaluates the costs of different combinations of strategies, where each combination would solve the 17,000 af annual overdraft experienced in the region (Borrego Water Dist., 2002, pp. 66-69).

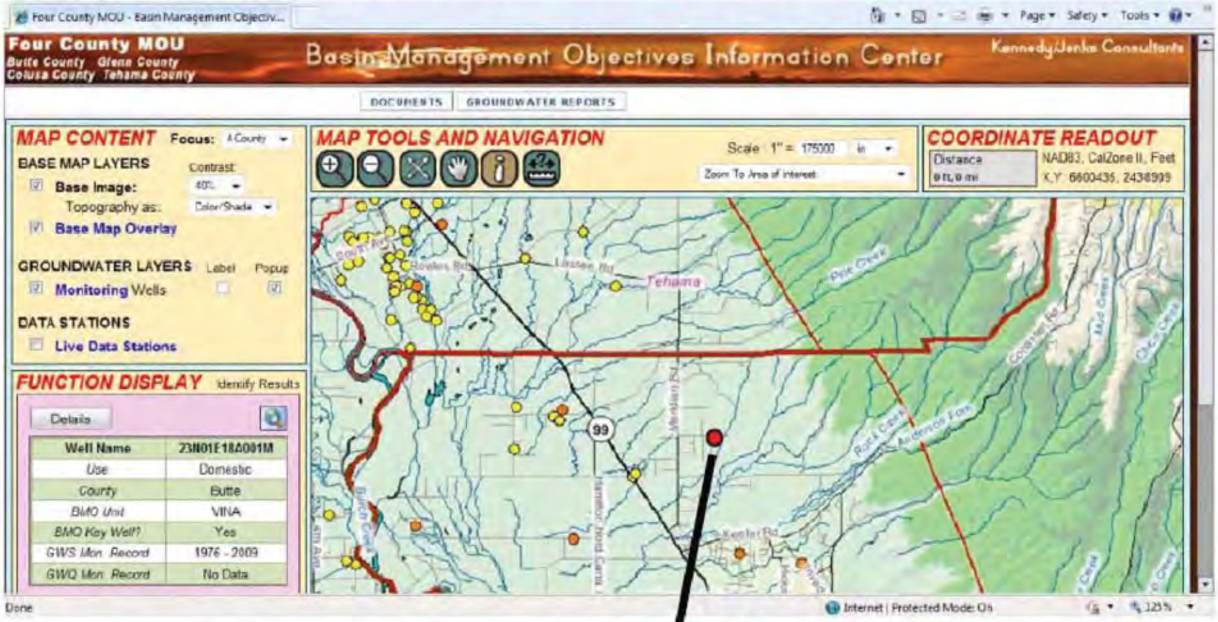
The GWMP for the **Eastern San Joaquin Basin** describes a process of modeling groundwater elevations and groundwater salinity based on a no-action (status quo management) scenario, projected to 2030. The plan considers a wide range of management options related to groundwater quantity, including options relating to surface supply, groundwater recharge and demand reduction. For each option, it compares the cost per acre-foot of water, infrastructure requirements, land requirements, effectiveness, and operation and maintenance requirements (N.E. San Joaquin County Groundwater Banking Auth., 2004, pp. 72-74, 85). However, it does not fully explain the "effectiveness" criterion, nor how this was calculated for each option. Nor does it quantify or model the basin impacts that would result from implementing each option or combinations of options. As a result, the infrastructure-based projects described later in the plan seem disconnected

	from the groundwater management options initially presented. The **Sonoma Valley** GWMP assesses the benefit of different management options by modeling them under a range of different water availability scenarios, taking into account projected changes in demand. The results are presented as quantified changes in groundwater storage and levels to 2030 for each scenario. The plan anticipates, but does not quantify, changes in extraction costs, quality degradation, streamflow, and environmental conditions (Sonoma County Water Agency, 2007, pp. 2-38 to 2-41). Similarly, the GWMP for the **Consolidated Irrigation District** uses an integrated surface and groundwater model to simulate changes in groundwater levels and flow direction (GEI Consultants, 2009, pp. 37-44). The **Sacramento Groundwater Authority** considers how climate change might impact future hydrologic conditions, and how such impacts might affect conjunctive use operations (Sacramento Groundwater Auth., 2008, pp. 55, 65). The **Central Sacramento County** GWMP models different management options and measures impacts in terms of water quality degradation, dewatering of wells, higher pumping costs, and ground subsidence. *See Table 7: Methods of controlling groundwater extraction.*
Formulating an implementation plan	In its implementation plan, **Butte County** sets out an implementation schedule for a series of actions. They are categorized into five GWMP "components" which aim to achieve seven management objectives. The actions range from cooperating with other parties to undertake groundwater monitoring, to sponsoring annual stakeholder meetings, to administering ordinances that relate to the proper construction and permitting of wells, limits on well pump capacity, well spacing, and minimum domestic well depths (Butte County, 2005, pp. 3-1 to 3-22). The **Fox Canyon Groundwater Management Agency**'s GWMP presents an action plan that categorizes and ranks its strategies (most of which are physically carried out by other agencies) more broadly, in 5-year intervals (Fox Canyon Groundwater Mgmt. Agency, et al., 2007, pp. 82-85).
Reporting on implementation	The **San Benito County Water District** provides an electronic, publicly available annual report on groundwater resources. The report includes water management activities, water supply sources, groundwater levels and trends, water demand, revenues, expected future conditions, and recommendations for refining management (Todd Engineers, 2009). The **Santa Clara Valley Water District** produces an electronic, publicly available annual report on groundwater protection and augmentation activities. The report includes information on current and project water requirements, programs to sustain the reliability of water supplies, and financial information (Santa Clara Valley Water Dist., 2009). The District also provides a monthly report on groundwater levels

(http://www.valleywater.org/Services/GroundwaterMonitoring.aspx).

Butte County's GWMP plans the development of quantitative BMOs, supported by a county ordinance (now Ch. 33A, Butte County Code) (Butte County, 2005, pp. 3-13, 13-20). That ordinance requires representatives from each BMO sub-area annually to report groundwater levels, groundwater quality, and subsidence monitoring results to the County water department to be assessed against the BMOs. Under its GWMP, **Butte County** also commits to pursuing funding to develop a web-based BMO Information Center for monitoring and reporting information. The Information Center's interactive maps show monitoring wells for four adjacent counties. Each well can be selected to show current and historical groundwater elevation and quality data (sometimes stretching back decades), color-coded to show compliance or non-compliance with the county's BMOs. *See Figure 1: Basin Management Objective Information Center for Butte, Tehama, Glenn and Colusa Counties – screenshot of map interface and individual well information.* The Information Center also houses annual BMO documents for each BMO sub-area, which explain how BMOs were developed for that year, and include monitoring data (http://www.buttecounty.net/Water%20and%20Resource%20Conservation/BMO.aspx).

Figure 1: Basin Management Objective Information Center for Butte, Tehama, Glenn and Colusa Counties – screenshot of map interface and individual well information (http://gis.buttecounty.net/bmoic3/GIs/Default.asp?loadfile=map.asp&county)



Four County MOU
Butte County Glenn County
Colusa County Tehama County

Basin Management Objectives Information Center

Kennedy/Jenks Consultants

MAP CONTENT Focus: A County

BASE MAP LAYERS — Contrast: 40%

☑ Base Image:
Topography as: Color/Shade

☑ Base Map Overlay

GROUNDWATER LAYERS — Label ☐ Popup ☑

☑ Monitoring Wells

DATA STATIONS

☐ Live Data Stations

Scale 1" = 175000 in

Zoom To Area of Interest

COORDINATE READOUT

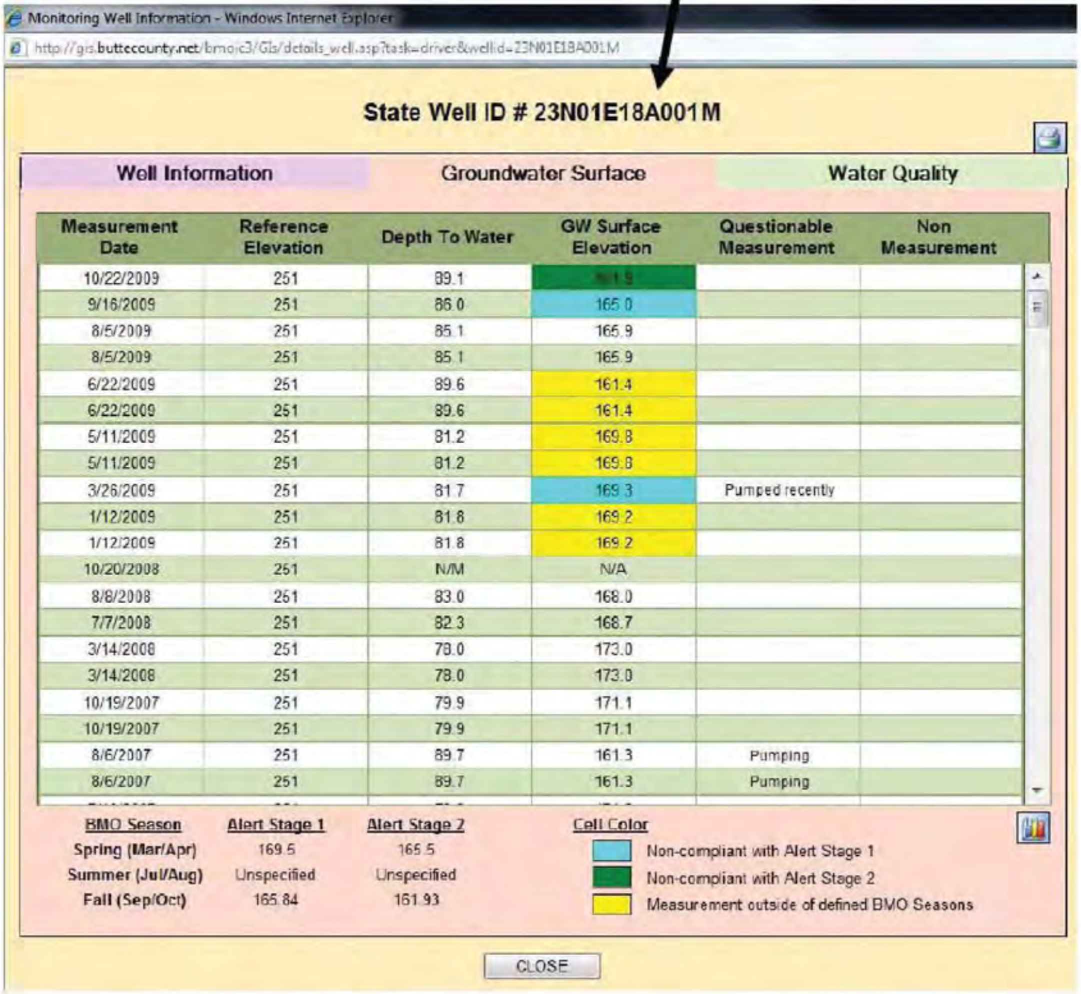
Distance 0 ft, 0 mi

NAD83, CalZone II, Feet
X,Y: 6600435, 2436999

FUNCTION DISPLAY Identify Results

Details

Well Name	23N01E18A001M
Use	Domestic
County	Butte
BMO Unit	VINA
BMO Key Well?	Yes
GWS Mon. Record	1976 - 2009
GWQ Mon. Record	No Data



State Well ID # 23N01E18A001M

Measurement Date	Reference Elevation	Depth To Water	GW Surface Elevation	Questionable Measurement	Non Measurement
10/22/2009	251	89.1	161.9		
9/16/2009	251	86.0	165.0		
8/5/2009	251	85.1	165.9		
8/5/2009	251	85.1	165.9		
6/22/2009	251	89.6	161.4		
6/22/2009	251	89.6	161.4		
5/11/2009	251	81.2	169.8		
5/11/2009	251	81.2	169.8		
3/26/2009	251	81.7	169.3	Pumped recently	
1/12/2009	251	81.8	169.2		
1/12/2009	251	81.8	169.2		
10/20/2008	251	N/M	N/A		
8/8/2008	251	83.0	168.0		
7/7/2008	251	82.3	168.7		
3/14/2008	251	78.0	173.0		
3/14/2008	251	78.0	173.0		
10/19/2007	251	79.9	171.1		
10/19/2007	251	79.9	171.1		
8/6/2007	251	89.7	161.3	Pumping	
8/6/2007	251	89.7	161.3	Pumping	

BMO Season	Alert Stage 1	Alert Stage 2
Spring (Mar/Apr)	169.5	165.5
Summer (Jul/Aug)	Unspecified	Unspecified
Fall (Sep/Oct)	165.84	161.93

Cell Color

🟦 Non-compliant with Alert Stage 1
🟩 Non-compliant with Alert Stage 2
🟨 Measurement outside of defined BMO Seasons

2. Cooperation and stakeholder participation

There are numerous barriers to local water agencies cooperating in groundwater management planning, including difficulties in building trust between local water management entities, and difficulties in matching benefits and funding burdens (GEI Consultants, 2009, p. 60). Further barriers prevent local water agencies from cooperating with other agencies, which undertake activities that can affect groundwater management, for example city land-use planning departments. Yet cooperation can save agencies time and money by reducing duplication in management efforts, taking advantage of economies of scale when contracting for similar goods and services, and avoiding inadvertently counterproductive management measures being taken by neighbors that are unaware of each other's actions. The examples given below show the wide range of groundwater management issues on which local water agencies can cooperate.

Table 3: Subjects of collaboration between water agencies in GWMPs

Collaborating to investigate GW resources	In 2001, a group of 15 local water districts in the San Joaquin Valley, including the **Poso Creek Regional Management** group of 7 districts, jointly prepared a report analyzing local groundwater resources to identify favorable areas for groundwater recharge and recovery (Kern-Tulare Water Dist. & Rag Gulch Water Dist., 2006, p. 17).
Collaborating on a strategic data collection plan	After the **Sacramento Groundwater Authority** identified significant inconsistencies between the data collection methods of its 14 member agencies, it initiated a Standard Operating Procedure (SOP) for collecting water level data, provided member agencies with DPH guidelines for the collection of water quality data, and offered training in the use of these standards (Sacramento Groundwater Auth., 2008, pp. 44, App.D). *NB: See also Table 6: Gathering and standardizing information on groundwater status and use.*
Coordinating to control groundwater-intensive development	An ordinance of the **Sierra Valley Groundwater Management District** (SVGMD) (Ordinance 83-01) puts in place arrangements commonly known as "assured water supply" rules. It requires any person who is seeking a land use approval from a local land use agency for a development that will use groundwater within the SVGMD's boundaries, to file documents regarding the water source with the SVGMD. The SVGMD makes a finding as to whether there is sufficient groundwater available, and only then may the local agency approve the development. *NB: In relation to groundwater intensive development, see also Table 8: Methods of managing groundwater demand.*

In addition to local agencies collaborating between themselves, a vast range of stakeholder groups has helped formulate GWMPs in California. Undeniably, broad stakeholder involvement takes time. Some GWMPs that cover large areas report up to 6 years of consensus-building and negotiation with tens of stakeholder groups (Sacramento County Water Agency, 2006, p. 1-4). However, broad stakeholder involvement brings multiple perspectives to help meet multiple objectives, and can help avoid conflicts that have derailed past groundwater management efforts, which were otherwise promising (Thomas, 2001, pp. 15-16, 19). Their involvement also helps to ensure that plans and programs are consistent across agencies, avoiding potential inter-governmental conflict, which can be particularly problematic in the groundwater sphere, when jurisdictional boundaries are blurred and may overlap (Thomas, 2001, pp.

24-25). Table 4 sets out examples of different structures for involving stakeholders in GWMPs.

Table 4: Structures for involving stakeholders in GWMPs

Structures for involving stakeholders	Stakeholders may be involved as part of a formal Stakeholder Group, or on formal committees such as a Technical Committee or Policy Committee formed to advise the GWMP agency, as is the case at the **Borrego Water District** (Borrego Water Dist., 2002, p. 17). Similarly, the **Glenn-Colusa Irrigation District**'s GWMP provides for establishing a Basin Management Committee consisting of stakeholder representatives, which is charged with creating a Technical Advisory Committee to set limits on withdrawals and mitigation measures. The Basin Management Committee considers changes to the GWMP, the rules and regulations required to implement it, and budget issues (Glenn-Colusa Irrigation Dist., 1995, p. 35}.
Involving a broad range of stakeholders	GWMPs have involved a wide range of stakeholders, including: • Other local water supply-oriented entities, including water districts, irrigation districts, city utility departments, water agencies, water conservation districts, public works districts, county water districts, private water companies, surface water masters, etc (Castaic Lake Water Agency, 2003, p. 4; Yuba County Water Agency, 2005, p. 29). • General agricultural and business interests, e.g. farm bureaus, and chambers of commerce (Sacramento County Water Agency, 2006, p. 3-10). • Local residents who pump groundwater, including agricultural users and domestic users, and representatives from water users associations (Butte County, 2005, pp. 3-17, 13-18; HydroMetrics LLC, 2007, p. 8). • Members of the public generally (HydroMetrics LLC, 2007, p. 8). • Local, regional, and state-level environment- and community-oriented entities, e.g. the Sierra Club, The Nature Conservancy, other local environmental non-profits, the League of Women Voters, recreation and parks districts, and community associations (City of San Diego Water Dep't, 2007, App.G; Sacramento County Water Agency, 2006, p. 3-10). • State participants, including staffers of members of the State Senate and Assembly, representatives of the Department of Water Resources, the Department of Fish and Game, Regional Water Quality Control Boards, and nearby State Parks (HydroMetrics LLC, 2007, p. 8; N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 4) • Federal participants, including the Natural Resource Conservation Service, U.S. Geologic Survey, U.S. Army Corps of Engineers (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 27).

Collaborating widely with agencies and stakeholders with different interest areas can attract numerous benefits, but may also invite disputes. GWMPs can address this proactively by incorporating explicit procedures for resolving disputes locally. Such procedures exist at various levels of formality (Table 5).

Table 5: Avoiding and resolving disputes when formulating and implementing GWMPs

Reaching consensus and avoiding disputes	The planning efforts of the **Northeastern San Joaquin Groundwater Banking Authority** and the **Sacramento Groundwater Authority** (formerly Sacramento North Area Groundwater Management Authority) both benefited from using the California Center for Collaborative Policy as a neutral third-party facilitator. These entities consider that using professional facilitators in the context of complex stakeholder negotiations is a key factor contributing to the success of their efforts (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 102; Thomas, 2001, p. 48).
Resolving disputes	The **Olympic Valley** and **Soquel Area** GWMPs explicitly nominate a process and a forum for resolving disputes. The body charged with implementing the GWMP hears disputes, receives submissions, holds public hearings, and makes decisions by majority vote, guided by "what action would serve the best interest of the public" (HydroMetrics LLC, 2007, p. 95; Soquel Creek Water Dist. & Cent. Water Dist., 2007, p. 136). The **Kaweah Delta Water Conservation District** uses a formal dispute resolution policy to avoid litigation in relation to groundwater management by encouraging mediation (Kaweah Delta Water Conservation Dist., 2006, App.C). The GWMP for the **Turlock Groundwater Basin** uses meetings of the Turlock Groundwater Basin Association, an association of local water agencies, to resolve issues associated with groundwater management. Meetings are open to the public (Turlock Groundwater Basin Assoc., 2008, pp. 1, 67).

3. Collecting information about groundwater context

Formulating a GWMP often occurs in complex and uncertain hydrological and ecological contexts. Collecting information about the status of groundwater bodies and groundwater use; standardizing data collection; sharing data; and considering the ecological impacts of management options all arise as concerns for GWMPs.

Historically, Californian local water agencies have strongly resisted metering groundwater use. This sentiment is slowly changing. Many special districts and some general districts now apply mandatory or voluntary groundwater metering. There is great variation in the motivations and practice of metering. Some agencies use metering as part of a program of imposing groundwater augmentation charges on users; others simply to improve their knowledge of the groundwater resource. Agencies require metering at different levels of use, and with different arrangements for reporting use.

There is much greater acceptance of the need to monitor groundwater levels, as distinct from use. However, many problems can strike a monitoring system, potentially compromising its comprehensiveness, accuracy, and the length of its record. Such issues appear common around the State. It is worth listing a small selection of these problems, to demonstrate the challenges that GWMPs should be designed to withstand. Economic factors can intervene: budget cuts can result in data gaps and infrequent measurements; older wells with long measurement records can be abandoned when they require expensive maintenance; and production wells may be used without any dedicated monitoring wells, which can risk inaccurate data caused by a non-static water surface (Kings River Conservation Dist., 2005, p. 4-26; Turlock Groundwater Basin Assoc., 2008, p. 55; Yuba County Water Agency, 2005, p. 31). Data may be collected but not compiled into a useful format for many years (Yuba County Water Agency, 2005, p. 31). In some cases, the construction data associated with monitoring wells may be unknown, so that it is not clear which of several aquifers are being monitored (City of Tracy, 2007, p. 27). Sometimes monitoring systems are simply not evaluated for their sufficiency, particularly for assessing whether a GWMP is meeting its objectives, or to model the safe yield, or to model predicted responses to management actions selected for the GWMP.

There is also significant variation across the State in relation to monitoring groundwater quality, which is much less commonly monitored outside of municipal areas (see e.g., Carpinteria Valley Water Dist., 1996, p. 2; Kreinberg, 1994, p. 3-5). This makes it quite difficult to draw links between overdraft and changing water quality, although it is not uncommon for agencies to report such a connection (Indian Wells Valley Cooperative Groundwater Mgmt. Group, 2006, p. 2; Stanislaus & Tuolumne Rivers Groundwater Basin Assoc., 2005, p. 12; Turlock Groundwater Basin Assoc., 2008, p. 41). Using standard data collection and management methodologies or protocols to ensure that the data collected are accurate and consistent is as important as monitoring.

Final, as ecological concerns are becoming more prevalent in GWMPs, the plans should include strategies to collect information to determine how ecological conditions influenced by groundwater management are faring.

Table 6 sets out examples of how agencies gather and standardize data on groundwater and its context.

Table 6: Gathering and standardizing information on groundwater status and use

Monitoring the status of groundwater bodies	The **Sacramento Groundwater Authority** (SGA) and **Western Placer County** GWMPs aim to maintain a "consistent long-term network" of wells to monitor groundwater elevation, each measured at least semi-annually. The wells are selected "to provide uniform geographic coverage" throughout the respective areas, using a grid of polygons, each containing a monitoring well. Non-producing wells with long records of consistently collected data are favored for inclusion in the network (City of Roseville et al., 2007, p. 3-8; Sacramento County Water Agency, 2006, p. 3-11; Sacramento Groundwater Auth., 2008, pp. 38-39). **Butte County**'s Groundwater Conservation Ordinance requires a countywide groundwater monitoring program that involves monitoring groundwater elevations either continuously using water level sensors, or otherwise at least four times per year (Butte County, 2005, p. 3-3), whereas semi-annual readings are much more common throughout the State. **Yuba County** uses its monitoring network "both for the health of the *long-term basin storage* and for *localized-short-term* impacts of pumping", with the latter particularly aimed at the effects of external groundwater transfers (Yuba County Water Agency, 2005, p. 30).
Metering groundwater use	The **Pajaro Valley Water Management Agency** generally requires every groundwater pump that produces 10 af/yr or more to be metered. It reads each flow meter twice per

	year for the purposes of assessing groundwater augmentation charges (Pajaro Valley Water Mgmt. Agency, 1993; 1996). The **Fox Canyon Groundwater Management Agency** requires metering of all wells except those which serve domestic purposes on parcels of land of one acre or less. The owner is responsible for associated expenses and must report groundwater use twice annually. The Agency undertakes random checks of meter reports to ensure they are accurate (Fox Canyon Groundwater Mgmt. Agency, et al., 2007, p. 49). In certain zones of the **Salinas Valley**, the **Monterey County Water Resources Agency** requires wells used for agricultural, urban or industrial purposes to be metered if they have a diameter of three inches or more, with operators required to report their use annually (Monterey County Water Resources Agency, 2006, p. 4-2).
Standardizing data collection and management, and sharing data	The primary purpose of the GWMP for the **Gillibrand Groundwater Basin** is to "present a standard methodology for the collection of data" on groundwater levels, use and quality, which applies to the basin's two largest water users, being a county waterworks district and a private mining company. The methodology covers measurement instruments, the frequency of measurement, quality assurance procedures, data storage, and procedures for reporting data (Geoscience Support Services Inc., 2007). The GWMP demonstrates that private and public entities can work together to standardize data collection and management. The **San Benito** GWMP includes in its list of actions for meeting its objectives, a plan to develop jointly with "all local agencies involved in water-related data collection and management ... a strategic program for data collection and management", aimed at supporting groundwater management decision-making. It should "specify the types of data to be collected and the frequency of measurement; evaluate the accuracy of data collection procedures; outline the structure, format, and units to be used in computerized databases; and indicate procedures to ensure data consistency and transfer among agencies" (Jones & Stokes Assoc., 1998, p. 65). The **Sacramento Groundwater Authority** is also developing a standard Water Accounting Framework for its member agencies. *See Table 10: Methods of protecting and enhancing recharge and examples of* water banking.
Collecting data relevant to the health of groundwater dependent ecosystems	The **Lassen County** GWMP "supports efforts to map and compile information on riparian habitats and phreatophyte vegetation" (Brown & Caldwell, 2007b, p. 3-7). Whereas much groundwater use for consumptive purposes in California depends on deep aquifers, ecosystems associated with wetlands may be connected to shallow aquifers. In such situations, monitoring the state of shallow aquifers is important to assessing ecological impacts. The **Squaw Valley Public Service District**'s GWMP includes monitoring shallow groundwater levels in the Olympic Valley meadow, which are connected to wetlands that have high ecological and aesthetic value (HydroMetrics LLC, 2007, p. 64).

4. A portfolio approach to groundwater management planning

A portfolio approach to groundwater management planning responds to information collected (including information from stakeholders) about the values of a resource, with goals that champion those values and multiple strategies for pursuing those goals. Goals include securing water supplies for consumptive purposes, maintaining or restoring ecosystems, protecting connected surface waters, and ensuring that groundwater use minimizes third-party impacts on society. This section sets out examples of agencies that adopt and pursue each of these goals, and the strategies they use to do so.

4.1 Securing groundwater supply for the long term

Securing groundwater supplies for consumptive purposes is the overriding focus of many GWMPs. The innovative strategies presented here emphasize an extensive range of options, beyond simply building more—or bigger—infrastructure solutions. They include limiting waste or drawdown in different ways, managing water demand using fees and education, using different water sources conjunctively, protecting and enhancing recharge, and water banking.

Table 7 outlines various mandatory measures to limit pumping, either directly, or by controlling developments that use groundwater intensively.

Table 7: Methods of controlling groundwater extraction: limiting waste, groundwater drawdown, or pumping

Defining sustainable yield and an acceptable operating range	The **Central Sacramento County** GWMP uses a "long-term average annual pumping limit" of 273,000 af/yr which stakeholders accepted as a negotiated limit "under which groundwater can be pumped and not exceed average natural recharge over a long-term period of time". Negotiators developed this limit by using groundwater models to quantify basin conditions in terms of four key areas of impact: • water quality degradation; • dewatering of wells; • higher pumping costs; and • ground subsidence, in 10-year increments from 1990 to 2030, comparing the impacts of different pumping levels to baseline pumping levels. The chosen sustainable yield level was found to maximize the yield of the aquifer while minimizing the four key impacts. In addition, the GWMP sets out an "operating range" of groundwater levels that will minimize these impacts for different areas of the basin (Sacramento County Water Agency, 2006, pp. 2-29, 3-23, App.A). However, the projections included in the GWMP do not include uncertainties, and it appears that historical hydrological data was used rather than data which attempts to factor in potential climate change impacts.
Taking action in response to non-compliance with BMOs	**Glenn County**'s GWMP, which itself is an ordinance, sets out a process for taking action in the event that its basin management objective for groundwater levels is breached. Its Technical Advisory Committee reports the details of the non-compliance to its Water Advisory Committee and the public, and recommends a course of action within five days. Negotiation with parties in the area is the preferred way to resolve the non-compliance, but should that fail, "the Water Advisory Committee may recommend a plan to the Board to modify, reduce or terminate groundwater extraction in the

	affected area for the remainder of that irrigation season", first in relation to wells involved in exports, then in relation to all other wells (Glenn County, 2000, [20.03.120], [120.103.130]).
Controlling pumping by using area limits	The **Western Canal Water District** GWMP envisions its Board of Directors annually re-evaluating its basin management objectives, including by considering whether to establish "quantitative limitations on groundwater extractions from particular areas . . . to limit adverse impacts of groundwater extractions on wells within and without the District" (Western Canal Water Dist., 2005, [3.2.3]). The District has adopted rules and regulations to implement and enforce its GWMP (Western Canal Water Dist., 2006); this would presumably be the vehicle for implementing pumping limits.
Controlling pumping by using individual extraction permits	The Groundwater Extraction Permit Ordinance of the **Mendocino City Community Services District** (MCCSD) requires any person who seeks "to extract groundwater for a new development, change in use, expansion of existing use, or to construct or modify a well" to obtain a permit. A permit allows the holder to extract only the quantity of water which is deemed necessary under "water use standards" that form part of the Ordinance. New wells are metered, and the District retains the right to enter the permit holder's premises to collect meter information. Violating the ordinance attracts penalties, including rescission of an extraction permit (Mendocino City Community Services Dist., 1990 (as amended, 2007), p. 21, 2007).
Controlling pumping by prohibiting new wells	**MCCSD**'s GWMP envisions prohibiting any new wells in times of serious water shortage, in addition to other mandatory measures (Mendocino City Community Services Dist., 1990 (as amended, 2007), p. 108). Under **Sutter Extension Water District**'s GWMP, after 1995, landowners who wish to construct new wells "may be required" to request the approval of the District's Board of Directors, which may approve the request with conditions (Sutter Extension Water Dist., 1995, p. 8).
Controlling water waste	The **Pajaro Valley Water Management Agency** has adopted an ordinance prohibiting water waste (Ordinance 92-1). The Ordinance defines water waste and prohibits listed wasteful practices within the boundaries of the Agency. It prohibits wasteful practices in agriculture as well as urban settings, although the former are specified in vague terms (e.g. "unreasonable evaporation loss" and "unreasonable deep percolation loss"). The Ordinance sets out a system of warnings followed by enforcement proceedings heard before a panel, and a penalty structure for first and repeated violations.
Adjudicating groundwater basins	Only one GWMP reviewed for this report—that of the **Borrego Water District**—lists adjudicating the groundwater basin as a management tool, albeit the lowest priority option (Borrego Water Dist., 2002, p. 74).
Limiting the expansion of water-intensive uses	Spurred by the recommendations of a local planning advisory group, **Borrego Water District**'s GWMP includes the following potential strategies to limit the development of water-intensive land uses (Borrego Water Dist., 2002, pp. 57-59): • prohibiting the as-of-right conversion of unused land to agriculture (agriculture would only be allowed to be developed under a permit to be issued after a public

	hearing and environmental review); • designating all unused land as "Desert Estate", which would allow 10 or 20 acre lot subdivisions, but would limit the use of non-native plants to a small portion of the lot; and • requiring future developments that seek a domestic water service from the Borrego Water District to sign over their rights to extract groundwater to the District (a strategy for which there is a precedent in the Borrego Valley).
Rotating/ fallowing cropland	The **Eastern San Joaquin Basin** GWMP very cautiously mentions "voluntary crop rotation", which would compensate farmers for removing cropland from production, as a groundwater management tool (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 87). The **Borrego Water District** more proactively includes in its GWMP a goal of obtaining funding to acquire agricultural land from willing sellers, and contemplates "paying farmers to not farm". The GWMP suggests that such a program could be funded by a water use fee, and sets out sample costs (Borrego Water Dist., 2002, pp. 60-64, 71-73).

GWMPs commonly include general statements about "raising public awareness" of overdraft and groundwater management or implementing "education measures" about conservation. However, relatively few refer to concrete actions to manage water demand; even fewer are specific to groundwater, or relate to non-municipal contexts. Moreover, no surveyed plan quantifies the effectiveness of such voluntary demand management programs. It is therefore difficult to describe best practice in this area.

Some examples of education measures contemplated by GWMPs include: water utilities participating in local fairs, inserts in water bills detailing water conservation tips, public signs, demonstration gardens for low water use, fact-sheets, water use audits and surveys, school education, rebates on water efficient appliances, water education classes and presentations (Borrego Water Dist., 2002, p. 73; City of San Diego Water Dep't, 2007, App.G-6; HydroMetrics LLC, 2007, p. 86; Mendocino City Community Services Dist., 1990 (as amended, 2007), pp. 111-112; Neuman, 1998; Orange County Water Dist., 2009, p. 1-9; Soquel Creek Water Dist. & Cent. Water Dist., 2007, pp. 59, 113-117, 125-127).

In the agricultural conservation sphere, programs include supporting organizations that carry out field irrigation evaluations and farm water conservation assistance and farm water tours (Kaweah Delta Water Conservation Dist., 2006, p. 16; North Kern Water Storage Dist. & Rosedale Range Improvement Dist., 1993, p. 10; Reclamation Dist. 2068, 2005, p. 3-9). More detailed examples of agricultural water demand reduction programs have been compiled outside of GWMPs (Agricultural Water Mgmt. Council, 2008).

Reducing water demand may, unfortunately, jeopardize the ability of agencies to carry out resource-intensive groundwater management programs by reducing revenue (Orange County Water Dist., 2009, p. 6-14). Ensuring that groundwater management programs are financially sustainable is vital (see section 4.4 of this report).

Fees can be used both to reduce demand and also to sustain other groundwater management actions. Table 8 sets out methods of reducing demand using fees.

Table 8: Methods of managing groundwater demand

Using fees to manage demands on aquifers	Under **Orange County Water District**'s much-celebrated pump-and-pay system, retail groundwater pumpers pay fees (a "replenishment assessment") to OCWD based on their metered usage. Additional fees (a "basin equity assessment") apply above a pre-determined allowable pumping amount, expressed as a ratio of the customer's groundwater pumping to its total water usage (the "basin production percentage", BPP). These fees are used to purchase imported water to replenish groundwater, administer water monitoring, and maintain the replenishment systems. The fees are structured so as to create a disincentive to use groundwater above the BPP (Orange County Water Dist., 2009, pp. 1-5, 5-28, 26-13). Similarly, the **Fox Canyon Groundwater Management Agency** imposes penalties on pumpers who extract more water than is allowed under the Agency's detailed allocation system. Its GWMP proposes using these penalties to purchase water to replace the extracted water (Fox Canyon Groundwater Mgmt. Agency, et al., 2007, p. 80). The **Soquel Creek Water District** uses tiered pricing (also described as increasing block water pricing) in the context of groundwater distribution systems for residential, commercial and agricultural purposes (Soquel Creek Water Dist. & Cent. Water Dist., 2007, p. 59).

Beyond manipulating demand by mandatory, voluntary or fee-based means, agencies may effectively increase their water supplies by using water from different sources in a conjunctive way (Table 9). This can involve introducing altogether new sources of water with different characteristic reliability profiles. For example, desalinated water and recycled water from municipal sources provide a supply that is largely unaffected by climatic conditions. Managing pumping distribution can "smooth" pumping pressure and ensure more uniform drawdown, avoiding deep cones of depression. This technique is also used to help avoid harming groundwater quality, and the flows and quality of connected surface waters.

Table 9: Methods of using different water sources conjunctively

Encourage greater surface water use	Agencies in the **Modesto Sub-Basin** and the **Chowchilla Groundwater Basin** regard annexation as a potential groundwater management tool, through in-lieu recharge—annexation enables areas reliant solely on groundwater to access surface water, thereby reducing pumping pressure (Chowchilla Water Dist.-Red Top Resource Conservation Dist. Joint Powers Auth., 1997, p. 13; Stanislaus & Tuolumne Rivers Groundwater Basin Assoc., 2005, pp. 28-29, 96). The **Soquel Creek Water District** uses incentives to encourage private well owners to cease using well water and connect to water distribution systems (Soquel Creek Water Dist. & Cent. Water Dist., 2007, p. 107).
Managing surface water-groundwater substitutions	The **Western Canal Water District** envisions transferring surface water out of the district, to be replaced by increased groundwater pumping. In such cases, monitoring and metering rules apply to ensure that: (1) the action does not create or exacerbate overdraft; (2) the additional volume pumped does not exceed the volume of surface water transferred; and (3) to mitigate any adverse effects of lower groundwater levels

	on farmers, e.g. by compensating them for additional energy costs (Western Canal Water Dist., 2005, p. 19, 2006, section VI).
Using desalinated seawater or brackish groundwater	Several agencies commit to investigating and pursuing desalinating brackish groundwater as an additional source of supply (City of San Diego Water Dep't, 2007, pp. 1-5, 3-49, 43-50; Monterey County Water Resources Agency, 2006, p. 2-1). **Alameda County Water District**'s Newark Desalination Facility (part of its Aquifer Reclamation Program) has desalinated brackish groundwater caused by past seawater intrusion, since 2003. The Program aims to meet multiple objectives: "1) increase useable basin storage, 2) improve overall water quality, 3) prevent movement of brackish water toward ACWD production wells, and 4) provide (future) supply augmentation" (Alameda County Water Dist., 2010, p. 6; 2001, pp. 4, A1-7, A1-8). Agencies in the **Fox Canyon Groundwater Management Agency**'s area have also seriously considered desalinating brackish groundwater to move pumping away from areas of lowering groundwater levels, increase supply, deal with water quality degradation, and potentially also restore coastal wetlands (Fox Canyon Groundwater Mgmt. Agency, et al., 2007, pp. 54-58). The **Soquel Creek Water District** intends to partner with the **City of Santa Cruz** to construct and operate a seawater desalination plant as a way to reduce pumping demands during dry years and reduce the potential for seawater intrusion (City of Santa Cruz & Soquel Creek Water Dist., 2010; Soquel Creek Water Dist. & Cent. Water Dist., 2007, p. 62).
Managing pumping distribution	**Orange County Water District**'s Temporary Coastal Pumping Transfer Program shifted pumping pressure from the coast to inland areas to minimize seawater intrusion (Orange County Water Dist., 2009, pp. 6-16). Similarly, modeling a shift in pumping pressure in the **Pajaro Valley** was found to "nearly double the basin sustainable yield" by preventing seawater intrusion (Pajaro Valley Water Mgmt. Agency, 2002, p. 3-4). In the inland area of **Indian Wells Valley**, managing the spatial distribution of new wells to minimize adverse effects on groundwater *quality* is a GWMP objective (Indian Wells Valley Cooperative Groundwater Mgmt. Group, 2006, p. 3). Similarly, the GWMP for the **Modesto Sub-Basin** contemplates optimizing well operations to achieve multiple different objectives, including "minimizing pumping costs, maintaining groundwater levels within a specified range . . . avoiding the migration of contaminant plumes", and improving downstream water quality by reducing high groundwater levels in areas of poor groundwater quality (Stanislaus & Tuolumne Rivers Groundwater Basin Assoc., 2005, p. 123). County well permitting requirements that apply within the **Fox Canyon Groundwater Management Agency**'s area shift pumping from a lower aquifer system to an upper aquifer system, to reduce the potential for overdraft and seawater intrusion in the lower system and ensure conjunctive use of both groundwater sources. Another tool considered in the area is shifting pumping to areas which are comparatively easy to recharge (Fox Canyon Groundwater Mgmt. Agency, et al., 2007, pp. 47, 76).

In addition to limiting extraction from a basin, agencies' GWMPs also plan to maximize "deposits" to a basin, by either protecting or enhancing natural recharge, or "banking" water for themselves or third parties, using recharge basins or injection wells (Table 10).

California's groundwater laws—or rather, legal uncertainties—challenge the development of groundwater banking. Legal uncertainties surround who is liable for displacing natural recharge; how to control the actions of third parties who are not party to management agreements, where their actions affect the quality or quantity of stored water; and liability for changes in water quality, to name a few (Foley-Gannon, 2008). One GWMP refers to "the monumental task of overcoming the institutional, political, financial and physical challenges of groundwater banking" (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 20).

Table 10: Methods of protecting and enhancing recharge and examples of water banking

Protecting existing recharge areas	As an initial step, the **Sonoma Valley** GWMP calls for "studies to identify groundwater recharge areas, to develop approaches to enhance groundwater recharge, and to identify ways to protect recharge areas from being covered by low permeability surfaces" (Sonoma County Water Agency, 2007, p. 3-3). The GWMP for the **Modesto Sub-Basin** takes a slightly more developed approach. It directs its implementing agencies to "[i]dentify areas having high potential for contributing to aquifer recharge and encourage agencies to communicate with land use planning entities to enact measures that will protect these lands from development that would reduce their value as recharge sites". It also includes, as a potential groundwater management tool, "pricing and incentive programs to encourage the continued use of surface water for flood irrigation" in areas with significant recharge potential (Stanislaus & Tuolumne Rivers Groundwater Basin Assoc., 2005, pp. 108, 120). The GWMP of the **Fox Canyon Groundwater Management Agency** considers a strategy of requiring "Low Impact Development" to maximize the infiltration of stormwater in new developments that overlie recharge areas, but does not outline how this might be achieved (Fox Canyon Groundwater Mgmt. Agency, et al., 2007, p. 69). The GWMP for the **Soquel-Aptos area** outlines an objective of participating in land use planning processes and supporting Santa Cruz County to protect and enhance groundwater recharge zones. Specific actions include supporting the County to update its groundwater recharge maps, supporting USGS in its work characterizing recharge areas, and pursuing a formal system for allowing water agencies to review development proposals that could affect primary recharge zones (Soquel Creek Water Dist. & Cent. Water Dist., 2007, pp. 75, 99, 100).
Enhancing recharge	The GWMP for the **Soquel-Aptos area** documents cooperation between Santa Cruz County, the GWMP agencies, and other neighboring water and resource agencies to introduce a recharge enhancement element to projects designed to control erosion and reduce stormwater runoff. The GWMP agencies pledge to "support County efforts to develop a program that will include standards regulating impervious surfaces . . . and provide for water impoundments, protecting and planting

	vegetation, and installing cisterns, dry wells, bioswales and other measures to increase runoff retention and groundwater recharge". They also commit to incorporating such design features in their own construction projects (Soquel Creek Water Dist. & Cent. Water Dist., 2007, pp. 102-103).
Replenish GW for later use	The **Santa Clara Valley Water District** manages extensive recharge facilities, including 90 miles of stream channel and spreader dams, 71 off-stream recharge ponds, and an injection well. Its recharge water sources are imported water and local surface water. The aim of the program is to "sustain groundwater supplies through the effective operation and maintenance of District recharge facilities" (Santa Clara Valley Water Dist., 2001, pp. 16-18). The District releases an annual report on its groundwater augmentation activities, the most recent of which states that 65% of groundwater pumped in the County originates from artificially replenished water (Santa Clara Valley Water Dist., 2010, p. i). The **Kings River Conservation District** GWMP includes the North Fork Group Program as an economical recharge strategy. It involves flooding seasonally fallowed agricultural areas and keeping canals full to increase percolation. It proposes to continue this Program and develop better ways of monitoring and measuring recharge (Kings River Conservation Dist., 2005, pp. 4-10, 14-11, 14-14, 16-14, 16-15).
Water banking for third parties	The **Arvin Edison Water Storage District** is party to a 25-year agreement with the **Metropolitan Water District of Southern California** (MWD), which began in 1997, to bank 250,000 ac-ft of MWD's water below Arvin-Edison. Water is delivered to Arvin-Edison using the Cross Valley Canal, and is returned (since 2003) during drought years, using the California Aqueduct. The program funded $25 million of capital works and reimburses Arvin-Edison for pass-through water banking costs (Arvin-Edison Water Storage Dist., 2003, p. 6). Arvin-Edison's Rules and Regulations specify that where it spreads water, or delivers surface water to landowners in lieu of them pumping, it has the exclusive right to use the groundwater storage to recover the water to supply district landowners or third parties (Arvin-Edison Water Storage Dist., 2006, cl.9). The **Sacramento Groundwater Authority**, which manages the North Area Groundwater Basin in cooperation with its 14 member agencies, is developing a centralized Water Accounting Framework (WAF) to support groundwater banking programs by "setting forth rules for operating a model groundwater bank, and monitoring the basin to ensure its sustainability". The SGA will maintain modeling and management tools needed to assess conjunctive use operations and maintain accounting systems for "deposits" and "withdrawals" (Sacramento Groundwater Auth., 2008, pp. 54-55). The GWMP of the **Northeastern San Joaquin County Groundwater Banking Authority**, which has eleven member agencies, adopts third party water banking and conjunctive use partnerships as a key element of the plan. This involves many individual sites, some then operating and some to be developed, numerous different surface supply sources, and all forms of recharge methods (direct injection, percolation, and in-lieu) (N.E. San Joaquin County Groundwater Banking Auth., 2004). The Authority recently released its Eastern San Joaquin Integrated

	Conjunctive Use Program Draft Environmental Impact Report (http://www.gbawater.org/news_events/public_notices.html).

4.2 Protecting connected surface waters

Californian law generally treats groundwater and surface water separately, though there are some exceptions to this (Hanak, et al., 2010, pp. 54-57). Some local agencies explicitly seek to ensure that groundwater pumping does not cause adverse impacts on surface waters, and implement corresponding measures (Table 11). These measures include studying the interaction between water bodies and reducing the effects of groundwater extraction on surface water.

Table 11: Methods of protecting connected surface waters

Explicitly recognize a goal relating to surface water impacts of groundwater pumping, or vice versa	The **Sonoma Valley GWMP** includes as a Basin Management Objective (**BMO**) to "protect against adverse interactions between groundwater and surface water" in relation to Sonoma Creek, which provides habitat for fish and other wildlife and is a source of supply for agriculture, businesses and residences (Sonoma County Water Agency, 2007, pp. 3-4). The **Olympic Valley GWMP** includes BMOs to "[p]romote viable and healthy riparian and aquatic habitats by avoiding or minimizing future impacts from pumping on stream flows" and to "[s]upport ongoing stream restoration efforts as they relate to groundwater management" (HydroMetrics LLC, 2007, p. 70). The **Western Canal Water District GWMP** aims both to "[m]inimize changes to surface water flows and quality that directly affect groundwater levels or quality" and also to "[m]imimize the effect of groundwater pumping on surface water flows and quality" (Western Canal Water Dist., 2005, [1.2]), although the GWMP does not appear to include any measures directly specifically to these aims.
Study surface water-groundwater interaction	A component of the **Soquel-Aptos area GWMP** is to use stream gauges and shallow groundwater monitoring wells adjacent to and in Soquel Creek to investigate surface water-groundwater interactions (Soquel Creek Water Dist. & Cent. Water Dist., 2007, pp. 77, 83). The **Olympic Valley GWMP** includes as management measures participating in stream/aquifer interaction studies, and annually analyzing baseflow trends, shallow groundwater level trends, and "changes in apparent stream-aquifer interaction" (HydroMetrics LLC, 2007, p. 71). The **Central Sacramento County GWMP** provides for updating and using an integrated groundwater and surface water model (Sacramento County Water Agency, 2006, p. 3-22).
Include measures to reduce pumping impacts on surface waters	The **Soquel-Aptos area GWMP** documents a policy of the Soquel Creek Water Management District to use incentives (such as reduced connection fees) to encourage groundwater users with wells located near Soquel Creek to connect to the District's distribution system. The GWMP includes modifying pumping distribution based on annual analyses of data collected under the District's groundwater and

	surface water data program, if, for example, it discloses evidence of baseflow depletion (Soquel Creek Water Dist. & Cent. Water Dist., 2007, pp. 107-108). The **Olympic Valley GWMP** envisions carrying out its BMOs related to surface water interaction by redistributing pumping to reduce surface water impacts and reducing pumping through conservation (HydroMetrics LLC, 2007, pp. 70-71). It does not explicitly address the potential reduction in runoff from conservation, and any consequences for streamflow.

4.3 Restoring ecosystems and minimizing ecological impacts

Many of the measures described above in relation to securing a long-term groundwater supply and protecting surface waters from the adverse impacts of groundwater pumping also help to protect ecosystems from adverse impacts. For example, conservation measures can reduce total groundwater extraction, limiting groundwater drawdown and therefore helping to maintain connections with wetlands. Conversely, some ecological projects can benefit groundwater storage, for example, stream restoration can result in greater recharge, increasing shallow groundwater levels and thereby increasing shallow groundwater storage (HydroMetrics LLC, 2007, p. 64).

Table 12 presents examples of agencies consciously aiming for and acting on ecological goals in groundwater management planning.

Table 12: Methods of restoring ecosystems and minimizing ecological impacts

Explicitly recognize ecological goals	The **Squaw Valley Public Service District's GWMP** includes as one of three overarching goals, to "protect, promote, and improve the environmental quality of Olympic Valley" (HydroMetrics LLC, 2007, p. 62). The Basin Management Objectives which underlie this goal include to: • "promote viable and healthy riparian and aquatic habitats by avoiding or minimizing future impacts from pumping on stream flows", • "minimize future impacts from pumping on identified wetlands", and • "support ongoing stream restoration efforts as they relate to groundwater management" (HydroMetrics LLC, 2007, pp. 63-64). The **Lassen County GWMP** includes as an objective to "maintain springs, seeps and riparian habitat" (Brown & Caldwell, 2007b, pp. 1-2).
Recognize and quantify environmental water demands	The **Alpine County GWMP** includes, by way of characterizing the aquifer and its context, environmental water demands, which "would include State and Federal wildlife refuges, and publicly or privately managed wetland habitat". However, for reasons that are unclear, these demands are allocated zero acre-feet of water (Brown & Caldwell, 2007a, p. 37). Similarly, the **Central Sacramento County Water Authority GWMP** recognizes "environmental water" as a source of demand, but simply notes that the demand has not been defined for various streams, and does not allocate responsibility for defining

	these demands or attempt to estimate them (Sacramento County Water Agency, 2006, p. 2-47). The **Soquel-Aptos area GWMP** seeks to "avoid alteration of stream flows that would adversely impact the survival of populations of aquatic and riparian organisms". This is defined as maintaining baseflow depletion (caused by pumping aquifers adjacent to identified streams) below current detection levels in order to avoid "significant adverse biological effect" (Soquel Creek Water Dist. & Cent. Water Dist., 2007, p. 76).
Mitigate effects of overdrafted areas on stream flows	The East Sacramento County Replacement Water Supply Project, described in the **Central Sacramento County Water Authority GWMP**, provides for releasing environmental water to the ecologically significant Cosumnes River. Although the Cosumnes River historically flowed year-round, it now has completely dry stretches during summer (primarily due to groundwater pumping), when flows are lost to the aquifer. The Project pre-wets the riverbed so that a smaller volume of late fall and summer flows is lost from the river to the underlying overdrafted aquifer, with adverse effects on riparian habitat (Sacramento County Water Agency, 2006, pp. 2-7, 2-44, 3-18).
Locate & design recharge basins to enhance wildlife habitat	The **Kings River Conservation District's GWMP** describes the 6000-acre Gragnani constructed wetland project, which was designed for habitat purposes. It has the secondary benefit of providing "in lieu recharge" by offering an alternative water supply to former groundwater users. The project was developed by the USDA Natural Resources Conservation Service purchasing conservation easements and recharging the wetlands using flood waters (Kings River Conservation Dist., 2005, pp. 4-2, 4-3). The Farmington groundwater recharge project described in the **Eastern San Joaquin GWMP** uses land leased from farmers at market rates, primarily to reduce saline intrusion and overdraft, and secondarily to provide seasonal habitat for migratory waterfowl. The American Society of Civil Engineers awarded it the Water/Environment Project of the Year in 2003 (N.E. San Joaquin County Groundwater Banking Auth., 2004, pp. 30, 133-137; http://www.farmingtonprogram.org/).
Remove non-native invasive species	The **San Diego City** water department supports programs that map and remove giant reed, tamarisk, and perennial pepperweed, which are local non-native invasive species that impact groundwater quantity, although the GWMP does not quantify what impact this has on water supplies (City of San Diego Water Dep't, 2007, p. 2-44).

4.4 Considering economic and financial sustainability

Economic factors are often the elephant in the groundwater management room. While many GWMPs cite the economically "unfeasible" nature of reducing groundwater usage through methods such as voluntary crop fallowing, no GWMP reviewed for this report quantified such impacts, nor estimated the impacts of *not* controlling groundwater use. Encouragingly, some GWMPs at least recognize the gravity of the latter.

Some agencies also seek to put in place measures to compensate well owners for the adverse economic impacts of decreasing groundwater levels.

Ironically, water shortages, including shortages caused by overdraft, threaten not just water users, but also the financial ability of agencies to undertake groundwater management actions to alleviate shortages. The costs of managing groundwater are likely to increase markedly during droughts, with additional enforcement and public outreach, for example, while the revenue of an agency may decrease as water usage drops. Finding a mechanism for sustainably funding groundwater management, under which customer water usage is decoupled from agency revenue is therefore vitally important (Mendocino City Community Services Dist., 1990 (as amended, 2007), p. 112).

Table 13 presents examples of agencies considering economic and financial sustainability in groundwater management planning.

Table 13: Methods of considering economic and financial sustainability

Considering the economic costs of not controlling groundwater use	The GWMP for the **Merced Groundwater Basin** acknowledges that long-term groundwater level declines due to pumping can increase the cost of pumping water and "restrict economic development" (AMEC Geomatrix Inc, 2008, p. 6). The **Eastern San Joaquin Groundwater Basin** GWMP recognizes that failing to address water management needs will lead to adverse impacts that will result in "business flight, job loss, loss of revenue for public services and general economic decline" (N.E. San Joaquin County Groundwater Banking Auth., 2004, p. 20). However, neither plan attempts to quantify these effects, or assess the long-term economic costs of overdraft against the short-term economic benefits of pumping.
Mitigating the economic costs of overdraft	The **Central Sacramento County** GWMP includes establishing a Central Basin Well Protection Program, including a "well protection trust fund". The fund will compensate owners of wells that have failed due to declining groundwater levels for the cost of deepening or replacing wells. The fund will be financed by fees collected as part of building permits for new construction, or well drilling permits. Only well owners who register their wells are eligible for compensation, so that the system also improves information about groundwater use. The fund came about because the sustainable yield negotiated for the GWMP was expected to result in further declines in groundwater levels, before they stabilized, and "current groundwater users should not have to subsidize future growth in the basin by paying the cost of deepening or replacing existing wells" (Sacramento County Water Agency, 2006, pp. 4-7 to 4-9). The recent economic downturn has resulted in the implementation of the fund being delayed (Sacramento Cent. Groundwater Auth., 2009, p. 22).
Ensuring sustainable funding for groundwater management	The **Mendocino City Community Services District** ensures that its groundwater management activities are sustainable even during droughts, when revenue may drop, by using a surcharge on wastewater and sewer usage fees to fund groundwater management (Mendocino City Community Services Dist., 1990 (as amended, 2007), p. 112).

PART SIX: CONCLUSION AND NEXT STEPS

The stage for California's groundwater management planning is a complicated and crowded one, filled with numerous actors of different types, who face difficult and sometimes critical groundwater depletion problems. Various institutional barriers often prevent these actors from talking to each other and sharing their stories of groundwater management successes and challenges. Since California's groundwater management planning laws do not involve State oversight, information about GWMPs is difficult to collect, and the state of Californian groundwater management has remained in shadow.

First and foremost, this report has shone a spotlight on some of these actors, and demonstrated that elements of their groundwater management planning efforts present promising and innovative approaches to local groundwater management. While their innovations are not necessarily common, they chart a path to better groundwater management that is practical and doable in a wide variety of different agency circumstances. It is hoped that local agencies around California will consider the approaches described here in formulating their own groundwater management actions, recognizing that management innovation is not necessarily precluded by scarce resources, or any particular statutory form.

Having used GWMPs to identify agencies whose water *planning* efforts stand out as exceptional in California, the next step is to determine whether these efforts are resulting in successful *implementation*, on the ground. Further research should ask of agencies questions like:

- Do you actively use your groundwater management plan—is it a "living" document, or a reference for occasional use?
- Which elements of your plan have been implemented?
- Did the process of formulating and implementing the plan lead to changes in how you manage groundwater?
- What are your success stories in formulating and implementing the plan?
- What constraints have you encountered in formulating and implementing the plan?

At a higher level, this report has contrasted California's groundwater management planning laws with those for urban water management plans, and suggested that water planning law has moved far beyond the current requirements and policy in relation to GWMPs. The many examples of innovative groundwater management planning by California agencies also confirm that the aspirations of GWMP law and policy are out of date.

Questions of State regulation of groundwater aside, there is a need to reform California's GWMP laws and policies to include demand management, and require greater analysis of the planning context, greater accountability through stakeholder participation, and the pursuit of multiple goals. Strengthening California's legislation for groundwater management planning provides a path towards better groundwater management, retaining the State's historical focus on local agencies driving local change. Reform that strengthen and update this legislation would build on a familiar base, and, judging from the significant number of plans in California, one with which many local agencies are comfortable. Law and policy should follow California's innovative local groundwater management agencies, and lead its groundwater agencies as a whole, down the path that this report suggests is both desirable, and also possible.

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Re: Comments on BDCP First Amendment to the Memorandum of Agreement Regarding Collaboration on the Planning, Preliminary Design And Environmental Compliance for the Delta Habitat Conservation and Conveyance Program in Connection with the Development of the Bay Delta Conservation Plan.

Comments Regarding Improved Transparency and Stakeholder Involvement in the BDCP Process.

Dear Director Glaser:

This office represents the Save the California Delta Alliance ("STCDA"). STCDA is a membership organization headquartered in Discovery Bay, California, and comprised of individuals and organizations interested in preserving and restoring the California Delta. Among others, STCDA represents the interests of recreational boaters who use the California Delta, individual homeowners who own waterfront property in the Delta and obtain their drinking water from the Delta, and businesses that earn their living from Delta-oriented activities, including recreational activities centered on the waters of the Delta. STCDA's primary mission is to improve habitat, support the recovery of listed species, improve water quality, and enhance recreational opportunities in the Delta.

STCDA represents an active and enthusiastic constituency and regularly turns out three to four hundred people at our town hall style meetings held in Discovery Bay.

STCDA would like to thank the United States Bureau of Reclamation ("Reclamation") for the opportunity to comment on the First Amendment to the Memorandum of Understanding ("Amendment") and for the opportunity to comment on ways to improve stakeholder participation in the BDCP process. We believe the invitation to comment is a much needed step in the right direction for a process that has gotten off track.

STCDA is particularly concerned with the dramatic change in the role and status of State Water Project Contractors ("SWP Contractors") and Central Valley Project Contractors ("CVP Contractors"), (collectively "Water Contractors") reflected in the Amendment. Below, we discuss the Water Contractor problem in the context of what we believe are systemic problems with the BDCP process that are manifested in the current Water Contractor controversy.

I. The Process Got Off On The Wrong Foot By Inaccurately Stating What The Major Federal Action Under Contemplation Actually Is.

We believe that one important problem with the BDCP process thus far is the failure to accurately describe and categorize the actions that are being taken within the well-established NEPA regulatory framework. Once actions are accurately described and categorized a better understanding of what is being done and what is and is not appropriate (and lawful) follows.

We believe that the entire process got off on the wrong foot because Reclamation has never accurately stated what the "major federal action" being contemplated is. 42 U.S.C. § 4332(c). The February 13, 2009, Notice of Intent to prepare an Environmental Impact Statement, 74 Fed. Reg. 7257, ("NOI") states that the proposed federal actions are issuance of ESA permits and implementation of one or more components of the BDCP. However, this is incorrect. The major federal action is continued operation of the CVP at increased rates of export through one of three alternative conveyance options ("Peripheral Canal"). Reclamation may recall that in recent litigation against the CVP Contractors it successfully argued that the major federal action at issue in that litigation was not the issuance of biological opinions but rather "planned coordinated operation of the Projects [CVP] that creates the jeopardy found by the BiOp." *Delta Smelt Consolidated Cases*, 686 F. Supp. 2d 1026, 1042 (E.D. Cal. 2009); *see also* U.S. Fish & Wildlife Service, *Habitat Conservation Plans*, *available at http://library.fws.gov/Pubs9/hcp_section10.pdf* (last visited Nov. 14, 2011) (noting that "[t]he purpose of the incidental take permit is to authorize the incidental take of a listed species, not to authorize the activities that result in the take"). Here, it is the continued operation of the CVP and SWP at increased export levels and with a Peripheral Canal that creates the jeopardy to the smelt and other listed species (and the take); the Habitat Conservation Plan ("HCP") and the take permits are incidental to the underlying activity.

The NOI's misstatement of the major federal action[1] has carried through the process and resulted in widespread public perception that the BDCP is "a twelve billion dollar canal dressed up as a habitat plan."

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[1] We are aware that BDCP prevailed against a similar claim in *Cent. Delta Water Agency v. U.S.F.W.S.,* 653 F. Supp. 2d 1066 (E.D. Cal. 2009). Two observations are in order with regard to *Central Delta Water Agency*: first the court dismissed the action on standing and ripeness grounds. *See id.* at 1083. The court did not reach the merits of whether the NOI was inadequate. Challenge to the project based on an inadequate NOI upon issuance of the Record of Decision is in no way impaired by *Central Delta Water Agency.* Second, and more to the point for BDCP policy guidance going forward, the court and the parties in *Central Delta Water Agency* entirely missed the appropriate claim, which is "informational injury." Had a properly framed complaint bringing an informational injury claim been brought, none of the factors cited by the court would have precluded the standing, ripeness, and finality requirements being satisfied. *See, e.g., Ctr. For Biological Diversity v. Brennan*, 571 F. Supp. 2d 1105, 1118 (N.D. Cal. 2007) (noting that "[i]t is well settled that plaintiffs may suffer injury as a result of a denial of information to which they are statutorily entitled" and "recognizing that a purely informational injury may be sufficient to confer standing") (citation omitted); *see also*

The term “peripheral canal” is the conventional label for transporting water from the north Delta to the Clifton Court Forebay outside of the rivers and sloughs of the Delta. Its use engenders instant public recognition and understanding of what is at stake. And it provokes instant response and controversy. Not using a conventional label when one is available strongly suggests to the reader that the writer is not referring to the object conventionally so labeled. It is misleading, particularly to the general public. *See also Railroaded Salmon,* available at http://vimeo.com/31740676 (last visited November 15, 2011) (noting “outrageous claim that new diversion facility is a conservation measure”); San Jose Mercury News, October 30, 2011, *Federal Delta water pact fails on every count,* available at http://www.mercurynews.com/opinion/ci_19217860 (last visited November 15, 2011) (criticizing BDCP “lack of transparency” and “favoritism toward water-export agencies”).

The habitat plan and conservation measures are actually very much needed and if properly fleshed out and evaluated could provide great benefit to the Delta. We think a robust habitat plan deserves broad public support. It would receive public support more readily if Reclamation were more forthcoming about identifying the Peripheral Canal for what it is, more clearly making a commitment to the HCP with or without a canal attached to it, and clearly stating an enforceable, ironclad, mechanism for ensuring that harmful levels of water export will never occur.

The current Water Contractor problem is another aspect of the mis-designation and lack of clarity in the BDCP process.

II. **The Amendment Dramatically Changes The Role Of The Water Contractors From That Contemplated In All Previous Documents And Understandings By Inappropriately Designating Them As “Responsible Agencies” Under CEQA and “Cooperating Agencies” Under NEPA.**

The Water Contractors are described for the first time in the BDCP process in the Amendment as “responsible agencies.” Amendment, Recital E and Paragraph II(I). The Federal White Paper on the 2011 Bay Delta Conservation Plan MOA (“White Paper”), issued in response to concerns expressed by Congressman Miller, is the first document to describe the Water Contractors as “Cooperating Agencies.” White Paper at 2. The term “Responsible Agency” is a statutorily defined term with a specific role under CEQA. Cal. Pub. Resources Code § 21069; CEQA Guidelines §§ 15096, 15381. The term “Cooperating Agency” is a term defined by the NEPA Implementing Guidelines with a specific role under NEPA. 40 C.F.R. §§ 1501.6 & 1508.5. Elevation to Responsible Agency and Cooperating Agency status gives the Water Contractors the ability to influence the process shielded from public view. *See* 43 C.F.R. § 46.225(d) (requiring Cooperating Agencies to make “a commitment to maintain the confidentiality of documents and deliberations during the period prior to the public release by the bureau of

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Daniel L. Mandelker, *Nepa Law and Litigation* § 4.17 (informational and procedural injury as injury in fact). Because informational injury was not litigated *Central Delta Water Agency* has no preclusive effect with respect to informational injury claims.

any NEPA documents, including drafts"). It also provides them with much more influence over the process. *See* 40 C.F.R. § 1501.6(a)(2) (Lead Agency must "[u]se the environmental analysis and proposals of cooperating agencies . . . to the maximum extent possible"); 40 C.F.R. § 1501.6(b)(3) (Cooperating Agency may prepare "environmental analysis including portions of the environmental impact statement"); 40 C.F.R. § 1501(b)(4) (Cooperating Agency to provide its own staff to work on preparation of EIS); 43 C.F.R. § 46.230 (Cooperating Agency may analyze data; develop alternatives; evaluate alternatives; estimate effects of implementing alternatives; carry out any other task related to the development of the EIS); 40 C.F.R. § 1506.5(c) (Cooperating Agency may select consultants engaged to prepare EIS).

Elevating the Water Contractors to Cooperating Agency status through a federal white paper that explains and defends the Amendment, when the term Cooperating Agency was nowhere used with respect to the Water Contractors prior to the White Paper, including in the Amendment, is not consistent with NEPA implementing regulations or standard agency practice.

Rather, NEPA implementing regulations contemplate that Cooperating Agencies will be designated through a formal process and will be publicly announced prior to beginning the scoping process, usually in the NOI. *See* 40 C.F.R. § 1501.5 (c) ("lead agencies *shall* determine by letter or memorandum which agency shall be the lead agency and which shall be cooperating agencies") (emphasis added); 40 C.F.R. § 1501.6(b)(2) (requiring that "[e]ach cooperating agency *shall* . . . [p]articipate in the scoping process") (emphasis added); Memorandum for the Heads of Federal Agencies, Subject: Reporting Cooperating Agencies in Implementing the Procedural Requirements of the National Environmental Policy Act (Dec. 23, 2004) (requirement for all federal agencies for "reporting the designation of Federal and non-federal cooperating agencies"); Memorandum for the Heads of Federal Agencies From James Connaughton, Subject: Cooperating Agencies in Implementing the Procedural Requirements of the National Environmental Policy Act (Jan. 30, 2002) (instructing heads of agencies to "identify as early as practicable" Cooperating Agencies); Memorandum For The Heads of Federal Agencies From James L. Connaughton, Subject: Report on Cooperating Agencies in Implementing the Procedural Requirements of the National Environmental Policy Act (May 26, 2005) (noting Lead Agencies are "designating formal cooperating agencies when beginning their NEPA process").

Here Reclamation did in fact comply with the regulations and standard agency practice by formally announcing the Cooperating Agencies in the NOI. However the Cooperating Agencies selected did not include the Water Contractors. Instead Reclamation properly designated The Army Corps of Engineers ("ACOE") and the United States Environmental Protection Agency ("USEPA") as the Cooperating Agencies. NOI, 74 Fed. Reg. at 7257. On the other hand, the NOI designates the Water Contractors as "Potentially Regulated Entities or PREs." NOI, 74 Fed. Reg. at 7258. It is clear that at issuance of the NOI, which is the appropriate time to select Cooperating Agencies, the Water Contractors were <u>not</u> to be designated as Cooperating Agencies because it is not appropriate for a *regulated* entity to serve as a Cooperating Agency.

Rather the federal *regulators*, ACOE and USEPA, were appropriately designated as the Cooperating Agencies[2].

Likewise, if the Water Contractors were to be Responsible Agencies under CEQA, the Notice of Preparation ("NOP") filed by DWR did not follow required procedures for doing so. CEQA Guideline[3] section 15082(a) provides that "the lead agency shall send to the Office of Planning and Research and each responsible and trustee agency a notice of preparation stating that an environmental impact report will be prepared." The distribution list attached to the NOP indicates that it was sent to twenty-two public agencies. The list does not include the Water Contractors. CEQA Guideline § 15096(b)(2) provides in pertinent part that "not longer than 30 days after receiving a Notice of Preparation from the Lead Agency, the Responsible Agency shall send a written reply by certified mail or any other method which provides the agency with a record showing that the notice was received. The reply shall specify the scope and content of the environmental information which would be germane to the Responsible Agency's statutory responsibilities in connection with the proposed project." The reply must also be sent to the State Clearinghouse. The State Clearinghouse website indicates that no reply was received from the Water Contractors. *See* SCH Number: 2008032062. That DWR did not follow required procedures for designating the Water Contractors as Responsible Agencies is not surprising because, like the NOI, the NOP identifies that Water Contractors not as Responsible Agencies but as "Potentially Regulated Entities." NOP at 2. Public accountability is the cornerstone of CEQA. Whatever discussions or understandings the Water Contractors may have had with DWR regarding their roles at the time of preparation of the NOP are irrelevant. CEQA requires a specific *public* process to be followed in designating Responsible Agencies.

The original Memorandum of Agreement Regarding Collaboration on the Planning Preliminary Design and Environmental Compliance for the BDCP ("Original MOU") referred to the Water Contractors as "SWP contractors" and "CVP contractors." Original MOU at 1. Like the NOI and NOP, the Original MOU designates the Water Contractors as "Potentially Regulated Entities." Original MOU, Recital B. Paragraph II(H) of the Original MOU deals with roles under NEPA and CEQA and describes DWR as the "lead agency under CEQA" and Reclamation as "one of the lead agencies under NEPA." Paragraph B(3) identifies the California Department of Fish and Game as a Responsible Agency but <u>does not</u> designated the Water Contractors as Responsible Agencies.

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[2] For an example of the formalities observed in the Cooperating Agency designation process *see Letter From U.S.E.P.A to U.S.F.W.S.,* Nov. 12, 2008, *available at* http://www.epa.gov/region9/water/watershed/sfbay-delta/pdf/EPA_CooperatingAgencyStatus_BDCP_111208.pdf (formally accepting designation as BDCP Cooperating Agency, outlining EPA's expected role, and identifying areas of EPA expertise that will be applied).

[3] We refer to the Guidelines by their common name. The Guidelines, however, are not suggestions. They are published in the California Code of Regulations at Title 14, Chapter 3. They are "binding on all public agencies in California." Guideline § 1500.

The Agreement Regarding Preparation Of A Joint Environmental Impact Report/Environmental Impact Statement For The Bay Delta Conservation Plan ("Lead Agency Agreement") spells out how tasks will be assigned to the consultant and how the work of the consultant will be directed. Lead Agency Agreement at C(1)(b). It reserves all these tasks to the Lead Agencies. Under the Amendment much of this critical phase of environmental review may well be ceded to the Water Contractors.

Through the White Paper, Reclamation has reached out to calm public concern about the new role of the Water Contractors by explaining that there is really nothing new or different. But that is not consistent with elevation to Cooperating and Responsible Agency status, which the record demonstrates is a new development, and which the relevant statutes and regulations demonstrate is a very different and elevated role.

III. **The Underlying Purposes Of Cooperating/Responsible Agency Status Are Not Served By Designating the Water Contractors as Cooperating/Responsible Agencies.**

The underlying purpose of Responsible Agency designation under CEQA is to ensure that an agency will consider the environmental impacts and develop mitigation measures to the maximum extent practicable before carrying out or approving any portion of a project for which it is responsible. CEQA Guideline § 15096. The underlying purpose of Cooperating Agency designation under NEPA is to help the Lead Agency identify and analyze environmental impacts. 43 C.F.R § 46.230. These purposes are not served, or intended to be served, by designating the Water Contractors as Responsible/Cooperating Agencies. The special expertise to identify impacts and require mitigation measures and the discretionary approval power for the project do not lie with the Water Contractors, but with other agencies (DWR, Reclamation, DFG, NMFS, USFWS, USEPA and several others who are already intimately involved in the project). Further expertise on Delta ecology and impacts will be obtained by engaging the CalFed Delta science team for independent peer review at the appropriate time. The Water Contractors' interest here is to obtain more water for their customers. This is a legitimate and essential purpose, but it is not commensurate with the underlying environmental protection purposes of Responsible and Cooperating Agency status.

We find unpersuasive the argument that because the Water Contractors must participate in decisions about diversion rates and are responsible for developing and implementing the HCP they need to be intimately involved in non-public portions of a coterminous NEPA/CEQA review of that plan as it is being developed. We also believe, as discussed below, that this combined process is contrary to NEPA-implementing regulations.

On the other hand, it is standard practice for project beneficiaries to finance, in part or in whole, the costs of preparing an EIR with explicit guarantees to the public that they will have no control over or participation in the process as a means of assuring the public that there is no undue influence. For example, typically developers applying to build a shopping center or hotel collaborate with planning staff on developing their project, make a payment into a trust account to cover the cost of preparing an EIR, then sit back and wait like everyone else while the EIR is being drafted. Why isn't this well-settled procedure, aimed at maintaining public trust, applicable here?

IV. The Combining of Scoping, Project Development and EIS Preparation "On The Fly" Leads To Outcome-Driven Results Rather Than Objective Analysis, Is Contrary To NEPA Implementing Regulations, And Is Particularly Troublesome If The Water Contractors Are Cooperating/Responsible Agencies.

The melding of scoping, project development, and formal environmental review tends to lead to outcome-driven results rather than an effective development of alternatives and an objective appraisal of the project's impacts. A better process would be to fully develop the Peripheral Canal alternatives and other elements of the project in a public scoping process before beginning the formal EIS/EIR preparation process. At this point the description of the canal alternatives is skeletal and several important alternatives have not yet been considered at all (at least not publicly). The most controversial aspects of the project remain as wholly unsettled controversies. We are aware that a menu of algorithms to determine levels of water export has been included in the latest public draft of the BDCP at section 3.4.2.1. The introduction to that section appears to indicate that adaptive management protocols might be used to determine how the diversion rates stated in section 3.4.2.1 might be modified if conditions require it. The introduction also seems to indicates that "a process has begun" to determine how long term operating criteria will be established. We are unsure if it is this process that will address adaptive management protocols. The introduction also refers the reviewer to the February 11 steering committee agenda and attached handouts for more information. However, the steering committee agenda/handout link on the website appears to be broken.

Although the short time allowed to prepare these comments did not afford us the luxury for a comfortable review of all BDCP documents, from what we have seen so far is appears that operating criteria, adaptive management protocols and triggers, and scoping of alternatives for diversion rates is very preliminary. Section 3.7.3.2 reveals that no "decision body" has yet been formulated to decide when water export levels need to be curtailed. Section 3.7.3.2, as it is currently formulated, could result in an indefinite impasse in any effort to change export rates in response to new information. For thirty years the crux of the Peripheral Canal issue has been how to attach iron clad guarantees that the canal cannot be operated in a way that will harm the Delta. Colloquially put, once the canal is built how will we ever be able to wrest control of the faucet from the Water Contractors? This issue must be resolved through public dialog before any NEPA review begins. Frankly, failure to address this issue up front spells doom for the Peripheral Canal this time around just as it did in 1982.

The BDCP appears to take the approach of using a simplistic algorithm to determine diversion rates. We believe that if a simplistic algorithm is to be used (which, given an algorithm's ability to peg a bright line standard, might well be the best approach), the trigger for allowing diversion to commence should be set at flood stage of the Sacramento River. This would require building additional storage capacity as flood flows may exceed the capacity of the CVP. We discuss this approach in more detail below under the heading "Yolo Bypass Alternative." It would seem at first blush that diverting only peak flows would produce abundant water (if there was capacity to store it) and would have the least potential for environmental harm. It would also set a bright line standard as to when diversion could take place. We would also like to ask how the algorithms published thus far capture a situation in which the preceding several years have been very dry years? Aren't ecological conditions different and in-stream flow more critical after a series of dry years? We did not see this in the materials that we were able to find. We think all of this needs to be addressed in one complete document with adequate time for the public to digest it and offer suggestions before NEPA review can begin. We think that these questions, and the fact that the reader has to scurry around gathering up meeting agendas to understand what the BDCP is about when EIS preparation is but weeks away confirms that the process is unduly rushed.

The combination of scoping with EIS preparation is also not consistent with NEPA implementing regulations. CEQ regulations indicate that if an agency intends to engage in combined scoping and EIS preparation, it should first adopt procedures that will govern such a combined process through notice and comment rulemaking. *See* 40 C.F.R. § 1501.7(b)(3) & § 1507.3. Neither DOI nor Reclamation has adopted the required regulations. We believe that such regulations would provide much needed guidance as to how a condensed scoping/EIS process would work and would provide safeguards that would prevent rushing into the process in a way that truncates public participation when it is needed in the development of alternatives[4].

One of the most contentious of the open questions is what level of water exports are being guaranteed to the Water Contractors. This is related to the failure to properly describe what the major federal action is. *See supra* Section I. The statement of project purpose in the NOI provides that deliveries of "full contract amounts" will be restored to the Water Contractors. However, this would be inconsistent with law because California Water Code section 85021 states that "the policy of the State of California is to reduce reliance on the Delta in meeting California's future water supply needs" and that each water district should develop its own supplies regionally. What is meant by restoring full contract amounts has never been settled and is the subject of heated controversy. *See, e.g., Letter from U.S.E.P.A. to Reclamation, USFWS, and NMFS,* June 10, 2010, *available at http://www.epa.gov/region9/water/watershed/sfbay-delta/pdf/EpaR9CommentsBdcpPurpStmt6-10-2010.pdf* (noting unclear purpose statement because "within the federal family, as well as in the broader debate, there seems to be little agreement on exactly" what is being promised to the Water Contractors).[5] Reclamation has been subject to repeated criticism for lack of transparency for this kind of issue from both the scientific community and the public at large. *See generally CalFed Science Review of the 2-Gates Project.*

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[4] Where a regulation contemplates notice and comment before adopting a procedure and the regulation is not followed a cause of action stating a claim for procedural injury immediately accrues. *Brennan*, 571 F. Supp. 2d at 1118.

[5] We are aware that the Lead Agencies replied to EPA's concerns by letter dated October 26, 2010.

It is our understanding that the project purpose statement will be revised and that revision will be announced to the public through publication of the draft EIR/EIS. This is particularly inappropriate. The project purpose statement and the effect of Water Code section 85021 are *threshold questions.* They should be addressed through *public* scoping at the very beginning of the process. It is also offensive to the public that issues of central public concern and controversy will be decided behind closed doors through negotiations with the Water Contractors, justified by the fact that the Water Contractors are Responsible/Cooperating Agencies.

V. **The Rushed Process Has Overlooked Important Alternatives And May Amount To Impermissible Segmenting.**

The Yolo Bypass Alternative Has Been Overlooked.

One of the BDCP guiding concepts is the "big gulp, little sip" principle, meaning that water diversion will be greatest at periods of high river flow and minimized when flow is less. We want to suggest that this concept should be applied to the canal alternatives through what we will call the Yolo Bypass Alternative(s)[6]. The Yolo Bypass intake is located upstream of the City of Sacramento and provides flood control for the City of Sacramento. During periods of very high river stage, the river overtops the Freemont Weir and vast quantities of water are diverted from the Sacramento River and down the Yolo Bypass. The limited time available to prepare these comments did not allow for hydrological research and exact figures, but those involved with the BDCP will be well aware that very large quantities of high quality water are diverted in this way. An intake for the Peripheral Canal could be located in some portion of the Yolo Bypass so a portion of these very high stage flows could be diverted and stored for use during the summer months. A variation of the Yolo Bypass Alternative would be to place an intake for the Peripheral Canal upstream of Sacramento on the Sacramento River. This intake would then capture the flood flows (and only the flood flows) and divert them for storage and beneficial use. Perhaps this intake could relieve the Yolo Bypass of its flood control function and the Freemont Weir could be operated solely for conservation values, enhancing the habitat and conservation functions of the Yolo Bypass. We are aware that the current capacity of the CVP is 15,000 cfs and this might present an operational limitation on how much water could be diverted at peak flow. Could some of the flood flow (in excess of 15,000 cfs) be stored underground? Could any of the Delta Islands be converted to storage (perhaps with a conservation and recreation benefit as well)? Could Los Vaqueros Reservoir accommodate some additional storage? What other storage options might be available? Again, we do not endorse any of these measures, but they are important aspects of the Peripheral Canal problem not currently being considered because they are the only canal alternatives thus far broached that would take no water that currently flows through the central and south Delta.

The Yolo Bypass Alternative also presents a tight fit with the purpose of the CVP:

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[6] This in no way implies that STCDA supports a Peripheral Canal. However, we point out that if a Peripheral Canal is to be analyzed under NEPA, all reasonable and prudent canal configurations should be analyzed.

> [The CVP's purpose is to] improve navigation, regulate the flow of the San Joaquin River and the Sacramento River, *control floods, provide for storage* and for the delivery of the stored waters thereof, for the reclamation of arid and semiarid lands and lands of Indian Reservations, and other beneficial uses, and for the generation and sale of electric energy.

Westlands Water District v. U.S., 337 F.3d 1092, 1095 (9th Cir. 2003) (citing Pub. L. No. 75-392, 50 Stat. 844, 850 (1937) (emphasis added)). In creating the CVP, Congress intended that flood control and providing water for beneficial use were two sides of the same coin: water diverted to control floods would go to beneficial use. Failure to consider the Yolo Bypass Alternative, with its flood control and storage features, and unique attribute of taking no Delta flows, might amount to failure "to consider an important aspect of the problem" and/or a failure to consider "the relevant factors" as specified by Congress. *Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co.,* 463 U.S. 29, 43 (1983). In this same vein, we have not yet seen where BDCP has considered improvements to navigation or even impacts on navigation. STCDA intends to look more closely at the BDCP and to provide substantive comments on the issue of navigation under separate cover.

We believe these examples demonstrate that the formal preparation of the EIS/EIR is not ready to start; that more time and public involvement should be put into identifying alternatives and fleshing out what are now skeletal plans into a complete plan before preparation of the EIR/EIS begins.

Failure To Include The 2-Gates Project And Other Gates Projects May Amount To Impermissible Segmenting.

Reclamation has been considering the 2-Gates Project and other gates projects in the Delta for some time. Recent inquiries were unable to determine what the exact status of these projects is. We understand that Reclamation is trying to validate the smelt-turbidity hypothesis through research currently being conducted by Jon Burau and Bill Bennett. It appears that the gates projects are still under consideration. The gates projects are within the BDCP project area and are intimately related to the water supply purpose of the BDCP as well as being proffered to benefit the smelt and reduce or eliminate the incidental take of smelt by operation of the CVP and SWP. Unless Reclamation has made a decision and will shortly be issuing a ROD on the gates projects adopting the no project alternative, failure to include the gates projects under the BDCP could well be impermissible segmenting of environmental review. The gates projects should be included as part of the BDCP (if they are still under consideration) or as alternatives to the Peripheral Canal. NEPA review of the gates projects should be conducted as a part of BDCP NEPA review. Given the potential for impermissible segmenting if the gates are not considered as part of BDCP review, the entire BDCP EIR/EIS might be found inadequate if the gates are not addressed.

VI. Improving The Stakeholder Process.

We believe that the credibility of the BDCP as a stakeholder driven process (as opposed to the current perception of a water grab by the Water Contractors) can only be restored by reconstituting the steering committee. We understand that the Brown administration has considered and rejected this idea. We believe that recent events portend an abrupt downhill slide for the BDCP in the court of public opinion unless decisive action is taken. We urge the Brown administration to reconsider.

All current members of the steering committee should be invited to stay on. It should be made clear that reconstituting the steering committee does not imply that current members have done anything other than contribute heroic amounts of time and energy in a selfless effort of public service.

A public outreach effort aimed at defining the additional slots on the steering committee should be undertaken. At a minimum, we believe additional slots should include representation of 1) navigation (this would include the interest of Delta marinas); 2) fishing (certain salmon fishing organizations have been among the BDCP's most vocal critics and they should be considered to fill a stakeholder slot); 3) local government; 4) Delta related business (perhaps the Delta Chamber of Commerce); and 5) Discovery Bay.

We include Discovery Bay because of the unique position of Discovery Bay and its extreme vulnerability to impacts of the BDCP. Discovery Bay is a community of waterfront homes built around a series of deep water bays connected to Delta waterways. An engineered water circulation system maintained by Reclamation District 800 moves water from Kellogg Creek to Old River through the bays. Approximately 3500 homes have attached docks fronting the bays. There is approximately two billion dollars worth of investment in direct boating access to the wider Delta from the bays and recreational use of the bays themselves.

First, Discovery Bay represents by far the largest concentration of waterfront homes in the Delta. Virtually all 13,000 residents of Discovery Bay are regular users of the Delta for recreation and many of them derive their livelihood from Delta related businesses. A broad cross section of currently unrepresented Delta interests would be captured by a Discovery Bay slot. Second, all BDCP alternatives are designed to change the hydraulic regime of the rivers and sloughs that feed our bays. What might appear as a minimal impact from the perspective of a coarse grained Delta-wide analysis might well prove catastrophic if examined with a specific focus on the bays of Discovery Bay. Silting of the bays could well result from increases in hydraulic residence time, which is a stated goal of several BDCP elements. Increases in dissolved oxygen are also of significant concern, as are changes in turbidity. Recent years have seen an epidemic of invasive weeds in Discovery Bay. The weeds have just recently been gotten under control. Changes in any or all of the parameters mentioned above could thwart our efforts to control these invasive species, which, if left unchecked, would obliterate the boating and recreational value of our bays.

Upon proper study, mitigation measures might be identified that could ameliorate these impacts. Such measures might include BDCP funding for ongoing weed control, BDCP funding for construction and operation of wing dams or other hydraulic structures at the mouth of each bay that could offset changes in circulation patterns, BDCP funding for implementation and ongoing operation of other yet to be identified measures to offset impacts to water quality. Likely, Discovery Bay mitigations measures could also contribute to enhanced habitat value and recovery of listed species.

VII. Specific Recommendations

Based upon the foregoing, we offer the following specific recommendations;

1) Reconstitute the Steering Committee as discussed above;

2) Reverse the decision to appoint the Water Contractors as Cooperating/Responsible Agencies.

3) Establish a process for the Water Contractors to fund the preparation of the EIR/EIS but with hands off the process itself.

4) Separate scoping, project development, and preparation of the EIR/EIS into distinct sequential phases with a tentative schedule as follows: complete scoping by June 30, 2012; complete project development by Jan 30, 2013; preparation of draft EIR/EIS Jan 30, 2013–June 30, 2013; public comment draft EIR/EIS June. 30, 2013–Nov. 30, 2013; preparation final EIR/EIS Nov. 30, 2013– Feb. 30 2014; public comment final EIR/EIS Feb.30, 2014–May 30, 2014; adopt ROD July 30, 2014.

5) Explicitly identify the most contentious issues and resolve them or develop a menu of resolutions for study through the public scoping process.

6) Reorganize the BDCP plan chapters so the Peripheral Canal is no longer referred to as a conservation measure and has its own chapter titled "Peripheral Canal Alternatives."

7) If the agencies wish to engage in combined scoping and EIS preparation in the future, initiate notice and comment rulemaking to adopt the appropriate procedures.

VII. Invitation To Make Public Presentation At Discovery Bay Town Hall Meeting And Conclusion.

We would like to take this opportunity to extend an invitation to hold a town hall meeting in Discovery Bay some time after the new year. We would envision a presentation of the BDCP by appropriate agency staff followed by a Q & A. Likely many attendees will be adamantly opposed to any Peripheral Canal. But talking to opponents is part of the NEPA process. This also might serve as an opportunity to explain the very real benefits of the HCP. It would also be an important gesture in reaching out to the general public, as opposed to interest group representatives who have dominated the BDCP process to date.

Conclusion

Thank you again for extending the invitation to comment and for considering our view.

Sincerely,

s/Michael Brodsky
Michael A. Brodsky Dated: Nov. 16, 2011

BDCP1738.

RECLAMATION
Managing Water in the West

Madera Irrigation District Water Supply Enhancement Project

Final Environmental Impact Statement

EIS-06-127

U.S. Department of the Interior
Bureau of Reclamation
Mid Pacific Region
South Central California Area Office
Fresno, California

June 2011

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

BDCP1738.

Madera Irrigation District Water Supply Enhancement Project
Final Environmental Impact Statement
Madera County, California

Lead Agency
Bureau of Reclamation
United States Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
South-Central California Office

Cooperating Agencies
U.S. Fish and Wildlife Service and U.S. Army Corps of Engineers

The United States Department of the Interior, Bureau of Reclamation (Reclamation), prepared this Final Environmental Impact Statement (EIS) for the Madera Irrigation District Water Supply Enhancement Project (MID WSEP). The MID WSEP Proposed Action is to construct a groundwater bank on the property known as Madera Ranch, west of the City of Madera, Madera County, California. The Federal actions include approval from Reclamation for MID to bank a portion of their CVP Friant Division contract water supply outside of its service area in the newly constructed groundwater bank at Madera Ranch and approval to extend the Reclamation-owned 24.2 Canal.

This Final EIS analyzes the potential direct, indirect and cumulative impacts of implementing the MID WSEP Reduced Alternative B (Proposed Action) which would involve banking CVP water outside the MID Service Area using select swales, recharge basins and the alteration of Reclamation-owned facilities.

This Final EIS also analyzes the potential direct, indirect and cumulative impacts of implementing the following alternatives:

- Alternative A - No Action Alternative;
- Alternative B - Banking CVP Water outside of the MID Service Area Using Swales and Alteration of Reclamation-owned Facilities;
- Alternative C - Banking CVP Water outside the MID Service Area without Swales and Alteration of Reclamation-owned Facilities;
- Alternative D - Banking CVP Water outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal (no alteration of Reclamation-owned Facilities).

For further information regarding this Draft Environmental Impact statement, contact:

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Appendices

List of Acronyms and Abbreviations

°F	Degree Fahrenheit
AF	Acre-feet
AF/year	Acre-feet per year
APE	Area of Potential Effect
ARPA	Archaeological Resources Protection Act
AST	Aboveground Storage Tank
BACT	Best available control technique
BGEPA	Bald and Golden Eagle Protection Act
BLM	Bureau of Land Management
BMPs	Best Management Practices
btu/hp-hr	British thermal units per horsepower per hour
CAA	Clean Air Act
CARB	California Air Resources Board
CDFG	California Department of Fish and Game
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
cfs	Cubic feet per second
CH_4	Methane
CIMIS	California Irrigation Management Information System
CMP	Congestion Management Plan
CNDDB	California Natural Diversity Data Base
CNEL	Community Noise Equivalent Level
CNPS	California Native Plant Society
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
Corps	U.S. Army Corps of Engineers
CRHR	California Register of Historic Places
CVP	Central Valley Project
CWA	Clean Water Act
cy	Cubic yard
dB	Decibel
dBA	A-weighted decibel (decibel logarithmic scale)
DBCP	1,2-dibromo-3-chloropropane
D_c	Critical water table depth
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EO	Executive Order
EPA	Environmental Protection Agency

ESA	Endangered Species Act
ET	Evapotransipiration
Feet MSL	Feet below mean sea level
FEMA	Federal Emergency Management Agency
FMMP	Farmland Mapping and Monitoring Program
Fresno MSA	Fresno metropolitan statistical area
FWCA	Fish & Wildlife Coordination Act
GAMAQI	Guide for Assessing and Mitigating Air Quality Impacts
GHG	greenhouse gases
GF Canal	Gravelly Ford Canal
GFWD	Gravelly Ford Water District
GPS	Global Positioning System
H_c	Critical capillary height
hp	Horsepower
IBC	International Building Code
ITA	Indian Trust Asset
L_{DN}	Day-night average sound levels
L_{EQ}	Equivalent sound level
LOS	Level of Service
M&I	Municipal and Industrial
MBTA	Migratory Bird Treaty Act
MCL	Maximum contaminant levels
MCMAVCD	Madera County Mosquito and Vector Control District
MGD	Million gallons per day
mg/L	Milligram per liter
mg/m^3	Milligram per cubic meter
MID	Madera Irrigation District
MOCP	Monitoring and Operational Constraints Program
MOU	Memorandum of Understanding
MROC	Madera Ranch Oversight Committee
MWMA	Mendota Wildlife Management Area
N_2O	Nitrogen dioxide
NA^+	Sodium ion
NAAQS	National Ambient Air Quality Standards
NAGPRA	Native American Graves Protection and Repatriation Act
NAHC	Native American Heritage Commission
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NO_2	Nitrogen dioxide
NO_x	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Services
NRHP	National Register of Historic Places
O_3	Ozone
O&M	Operations and maintenance
OHWM	Ordinary high water mark

PG&E	Pacific Gas and Electric
PM_{10}	Particulate matter between 2.5 and 10 microns in diameter
$PM_{2.5}$	Particulate matter less than 2.5 microns in diameter
PPB	Parts per billion
PPM	Parts per million
PVC	Polyvinyl chloride
RCP	Reinforced concrete pipe
Reclamation	Bureau of Reclamation
ROD	Record of Decision
ROG	Reactive organic gases
ROW	Rights of way
RWQCB	Regional Water Quality Control Board
SHPO	State Historic Preservation Officer
SIP	State Implementation Plan
SJRRP	San Joaquin River Restoration Program
SJVAB	San Joaquin Valley Air Basin
SJVAPCD	San Joaquin Valley Air Pollution Control District
SO_2	Sulfur dioxide
SO_x	Sulfur oxides
SR	State Route
SSJVIC	Southern San Joaquin Valley Information Center
SWP	State Water Project
SWPPP	Storm Water Pollution Prevention Program
SWRCB	State Water Resources Control Board
TDML	Total Daily Maximum Loads
TDS	Total Dissolved Solids
µg/L	Micrograms per liter
$\mu g/m^3$	Micrograms per cubic meter
µS/cm	MicroSiemens per centimeter
U.S.C.	United States Code
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	Underground storage tank
V/C	Volume-to-capacity
VOC	Volatile organic compounds
WSEP	Water Supply Enhancement Project

Executive Summary

Please note that text that has been revised since the Draft Environmental Impact Statement (EIS) is marked with a vertical line in the right margin. Text found to be redundant or unnecessary in the Draft EIS has been removed.

ES-1 Introduction

Madera Irrigation District (MID) approved a Water Supply Enhancement Project (WSEP) located on the property known as Madera Ranch, west of the city of Madera, in Madera County, California in September 2005. This approval was based on their Final Environmental Impact Report (EIR) completed for compliance with the California Environmental Quality Act (CEQA). At that time, there was no federal action that would require compliance with the National Environmental Policy Act (NEPA).

The U.S. Department of the Interior, Bureau of Reclamation (Reclamation) commented on the Draft EIR, stating that once MID proposed a federal action, Reclamation would need to complete and satisfy all NEPA requirements as well as all other legal requirements before approving any federal action. A Draft EIS was initiated in response to MID's request that Reclamation approve the banking of MID Central Valley Project (CVP) water outside MID's service area in the proposed WSEP, and the modification of the 24.2 Canal, a federal facility.

Pursuant to the requirements of NEPA, Reclamation published a Notice of Intent to prepare a Draft EIS and Notice of Public Scoping Meetings in the *Federal Register* on September 28, 2007. Reclamation and MID held Draft EIS scoping meetings at MID's offices in Madera on October 22 and 29, 2007. Before the meetings, public notices were posted at MID's offices and published in the *Madera Tribune* and the *Fresno Bee* announcing the time, date, location, and purpose of the meetings. Each scoping meeting included an overview of the meeting's purpose, the proposed project and alternatives, potentially significant environmental issues, and opportunities for future public involvement.

Reclamation filed a Notice of Availability in the *Federal Register* on July 28, 2009 for the Draft EIS. The Draft EIS underwent public review for 60 days, during which time Reclamation held a public meeting. After comments had been received, Reclamation prepared responses to comments and has included them in this Final EIS. Reclamation upon filing the Notice of Availability for this Final EIS in the *Federal Register* will circulate this Final EIS for at least 30 days before issuing a Record of Decision (ROD).

This Final EIS has been completed for compliance with NEPA by Reclamation as the Federal lead agency. Reclamation has been coordinating with the U.S. Army Corps of Engineers (Corps) and U.S. Fish and Wildlife Service (USFWS) to analyze the potential direct, indirect and cumulative environmental impacts of the Proposed Action.

ES-2 Purpose and Need

Currently, farmers in MID's service area use a combination of groundwater and surface water. During dry years, there is not adequate surface water to meet the water demand and groundwater pumping increases substantially. The amount of groundwater that has been pumped from the aquifer in the vicinity of Madera Ranch has exceeded the amount of water that has recharged the aquifer, resulting in groundwater overdraft. Even in wet years, the groundwater basin is in severe overdraft because groundwater pumping is steadily increasing for agricultural use as well as municipal and industrial (M&I) use. This overdraft has caused the water table to decline and groundwater quality to degrade and has resulted in excess space in the aquifer that could be used to bank surface water.

In the vicinity of Madera Ranch, the water table has declined more than 90 feet over the last 60 years. These conditions have made it increasingly expensive for farmers to pump groundwater. Additionally, in many years, MID has been unable to deliver sufficient surface water to farmers because water is available primarily during the early months of the year when irrigation demand is low, and often water is available only for short periods of time during the growing season.

The purpose of the proposed federal action is to:

- enhance water supply reliability and flexibility by using the excess aquifer space for surface water storage (water banking);
- reduce existing and future aquifer overdraft;
- reduce groundwater pumping costs;
- increase groundwater quality;
- encourage conjunctive use in the region as a means toward regional self-sufficiency.

ES-3 Description of the Project Alternatives

To meet these project purposes, MID proposes to implement the WSEP, by which MID would bank a portion of their CVP water from the San Joaquin and Fresno Rivers and other non-CVP water in the aquifer underlying Madera Ranch. Water would be banked in the aquifer, and 10% of the water would be left behind to reduce overdraft.

This Final EIS analyzes the potential direct, indirect and cumulative impacts of implementing the MID WSEP Reduced Alternative B (Proposed Action) which would involve banking CVP water outside the MID Service Area using select swales, recharge basins and the alteration of Reclamation-owned facilities.

This Final EIS also analyzes the potential direct, indirect and cumulative impacts of implementing the following alternatives:

- Alternative A - No Action Alternative;
- Alternative B - Banking CVP Water outside of the MID Service Area Using Swales and Alteration of Reclamation-owned Facilities;
- Alternative C - Banking CVP Water outside the MID Service Area without Swales and Alteration of Reclamation-owned Facilities;
- Alternative D - Banking CVP Water outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal (no alteration of Reclamation-owned Facilities).

ES-3.1 Alternative A

Under the No Action Alternative, MID would not bank MID CVP water (MID Long-Term Water Service Contract supplies from both the Friant Division and Hidden Unit) on Madera Ranch (Figure 2-1) and Reclamation's delivery canals would not be enlarged. MID may bank non-CVP water on the property, and other limited on-site water banking and recovery facilities may be constructed if MID is able to find participants and funding to support these efforts. MID estimates that under the No Action Alternative, MID only could apply less than 5,000 acre-feet (AF) per year (AF/year) of their own non-CVP water, and recovery operations likewise would be limited if Reclamation-owned facilities were not altered. The number of other participants and amount of water they could bring to the project are uncertain. If the proposed project does not proceed, MID likely would sell the property to other agricultural interests. MID has had numerous offers from prospective buyers, including dairy, orchard, and row crop farmers. The No Action conditions would allow for agricultural activities.

ES-3.2 Alternative B

Alternative B would be completed in two phases. Phase 1 would involve only recharge-related facilities. Phase 2 would involve supplemental recharge facilities and facilities for recovery of banked water. Reclamation would approve a total banking capacity of 250,000 AF of MID CVP water outside the MID service area and issuance of an MP-620 permit (a Reclamation Mid-Pacific Region-specific permit issued for additions or alterations to Reclamation-owned conveyance and distribution facilities) for Lateral 24.2. After alteration of the Reclamation-owned facilities (Lateral 24.2) and certain MID facilities, MID would be able to recharge and recover a maximum of 55,000 AF annually.

Phase 1 activities would involve:

- reconditioning and extending canals to provide at least 200 cubic feet per second (cfs) of conveyance capacity into Madera Ranch;
- constructing approximately 55 acres of recharge basins on current agricultural land to regulate flow, remove sediment, and provide some recharge;
- applying recharge flows to approximately 700 acres of swales; and
- integrating approximately 2,600 acres of Madera Ranch row crops and vineyards into an in-lieu recharge program in which surface water periodically would be served in lieu of groundwater pumping subject to approval by the Madera Ranch Oversight Committee (MROC).

Phase 2 activities for recharge and recovery facilities would involve:

- additional upgrades to existing canals,
- construction of up to 1,000 acres of new on-site recharge basins and canals as required to supplement Phase 1 facilities and achieve 200 cfs of recharge capacity (if required),
- use of up to 15 existing wells for recovery,
- installation of up to 49 new wells and recovery pipelines (in phases over several years) to provide 200 cfs of recovery capacity, and
- installation of up to 12 lift stations on MID canals and one lift station on Gravelly Ford Canal (GF Canal) (in phases over several years) to provide 200 cfs of pump-back capacity into the MID service area.

ES-3.3 Reduced Alternative B

Reduced Alternative B represents a scaled-back version of Alternative B that uses fewer swales in order to minimize effects to vernal pools and limits the number of recharge basins to the number needed for the project to be practicable. It is included in the Final EIS as a revision to Alternative B to allow the public to see how the project has been modified, demonstrate how effects have been reduced, and facilitate the Corps use of this document in their permitting of the project. As with Alternative B, Reduced Alternative B would complete the water bank in two phases. Phase 1 would involve constructing necessary delivery infrastructure improvements (except for the Section 8 canal southwest extension), using select natural swales for recharge (550 acres versus 700 acres as proposed under Alternative B), and installing approximately five soil berms to direct recharge flows. Phase 2 would involve constructing a limited number of recharge basins (323 acres versus up to 1,000 acres under Alternative B) and facilities for recovery of banked water. Reclamation would approve banking of CVP water outside the MID service area and alteration of Reclamation-owned facilities.

ES-3.4 Alternative C

Alternative C is a variation of the Proposed Action that would complete the water bank in two phases and replace natural swale recharge solely with recharge basins. Phase 1 would involve recharge-related facilities only. Phase 2 would involve facilities for recovery of banked water. Reclamation would approve banking of CVP water outside the MID service area and alteration of Reclamation-owned facilities.

Phase 1 activities would involve:

- reconditioning and extending existing canals to provide at least 200 cfs of conveyance capacity into Madera Ranch,
- constructing up to 1,000 acres of new on-site recharge basins and canals as required to achieve 200 cfs of recharge capacity, and
- integrating approximately 2,600 acres of Madera Ranch row crops and vineyards into an in-lieu recharge program in which surface water periodically would be served in lieu of groundwater pumping subject to approval by the MROC.
- Phase 2 recharge and recovery facilities would involve:
- up to 15 existing wells for recovery;

- up to 49 new wells and recovery pipelines (in phases over several years) to provide 200 cfs of recovery capacity; and
- up to 12 lift stations on MID canals and one lift station on GF Canal (in phases over several years, total of 13 lift stations) to provide 200 cfs of pump-back capacity into the MID service area.

ES-3.5 Alternative D

Under Alternative D, MID would enter into an agreement with Gravelly Ford Water District (GFWD) to improve the GF Canal to allow water to be conveyed from the San Joaquin River through the GF Canal to Madera Ranch for banking of water and recovery of water from the ranch back through the canal to the river. The existing GFWD pumping plant would be enlarged; the existing, associated pipeline replaced with a larger-diameter line; the GF Canal re-graded to a flat-bottom (zero slope) configuration to allow two-way flow; a new connection to the river constructed to allow recovery water to reach the river without flowing through the pumps; and appropriate gate structures constructed. On-site improvements allowing water banking and extraction, including a pumping plant and pipeline to allow distribution of water uphill from the GF Canal, would be constructed.

MID would complete Alternative D in two phases. Phase 1 would involve recharge-related facilities only. Phase 2 would involve supplemental recharge facilities and facilities for recovery of banked water. Reclamation would approve the banking of CVP water outside the MID service area as described under Alternative B. No alteration of Reclamation-owned facilities would occur under Alternative D.

Phase 1 activities would involve:

- reconditioning of existing canals to provide at least 200 cfs of conveyance capacity into Madera Ranch;
- construction of approximately 26 acres of recharge basins on current agricultural land to regulate flow, remove sediment, and provide some recharge;
- application by MID of recharge flows to approximately 700 acres of swales; and
- integration of approximately 2,600 acres of Madera Ranch row crops and vineyards into an in-lieu recharge program in which surface water would be periodically served in lieu of groundwater pumping subject to approval by the MROC.
- Phase 2 recharge and recovery facilities would use or include:
- up to 15 existing wells for recovery,
- up to 49 new wells and recovery pipelines (in phases over several years) to provide 200 cfs of recovery capacity, and
- one lift station on GF Canal to provide 200 cfs of pump-back capacity to the San Joaquin River.

ES-4 Overview of Environmental Impacts

The EIS evaluates the direct, indirect, and cumulative environmental changes and/or impacts on the following resources:

- Aesthetics
- Agriculture
- Air Quality
- Biological Resources
- Cultural Resources
- Environmental Justice
- Geology, Soils, Seismicity, and Erosion
- Global Climate
- Growth-Inducing Effects
- Hazards, Public Health, and Safety
- Indian Trust Assets
- Land Use
- Noise
- Public Services and Utilities
- Socioeconomics
- Traffic and Circulation
- Water Resources
- Water Supply
- Wetlands

A comparison of the Alternative impacts is displayed in the following Executive Summary table.

Table ES-1 Executive Summary Impacts and Mitigation Table

Potential Impact	Alternative	Potential Impact Determination	Avoidance/Mitigation Measures
Aesthetics			
AES-1: Temporary Degradation of Visual Character or Quality from Construction-Related Activities	B, Reduced B, C, D	Yes	
AES-2: Degradation of Visual Character or Quality from New Permanent Features	B, C, D	No	
Agriculture			
AG-1: Alteration of Madera Ranch Agricultural Operations	B, Reduced B, C, D	No	
AG-2: Conflict with Williamson Act Contracts	B, Reduced B, C, D	No	
AG-3: Loss of Agricultural Land Designated as Prime Farmland or Farmland of Statewide Importance	B, C, D	Yes	AG-1
AG-4: Conflict with Local Zoning Designations	B, Reduced B, C, D	No	

Air Quality			
AQ-1: Generation of Construction Emissions in Excess of Federal *de minimis* Threshold Levels	B, Reduced B, C, D	Yes	AQ-1, AQ-2
AQ-2: Generation of Operational Emissions in Excess of Federal *de minimis* Threshold Levels	B, Reduced B, C, D	No	
AQ-3: Result in a Cumulatively Considerable Net Increase of Any Criteria Pollutant for which the Region Is in Nonattainment under an Applicable Federal or State Ambient Air Quality Standard (Including Releasing Emissions that Exceed Quantitative Thresholds for Ozone Precursors)	B, Reduced B, C, D	Yes-cumulative	AQ-1, AQ-2
Biological Resources			
BIO-1: Temporary Disturbance of California Annual Grassland and Alkali Grassland during Construction	B, Reduced B, C, D	No	
BIO-2: Permanent Removal of California Annual Grassland and Alkali Grassland Habitats during Construction	B, Reduced B, C, D	Yes	BIO-1
BIO-3: Loss or Disturbance of Iodine Bush Scrub or Sensitive Plant Species Habitat as a Result of Construction	B, Reduced B, C, D	Yes	BIO-2a, BIO-2b
BIO-4: Potential for Construction-Related Mortality of Sensitive Vernal Pool Crustaceans	B, Reduced B, C, D	Yes	BIO-2a, BIO-2b
BIO-5: Potential for Operation- and Maintenance-Related Mortality of Sensitive Vernal Pool Crustaceans	B, Reduced B, C, D	Yes	BIO-2a, BIO-2b
BIO-6: Potential for Construction-Related Mortality of San Joaquin Tiger Beetle	B, Reduced B, C, D	No	
BIO-7: Potential for Operation- and Maintenance-Related Mortality of San Joaquin Tiger Beetle	B, Reduced B, C, D	No	
BIO-8: Potential for Construction-Related Mortality of California Tiger Salamander	B, Reduced B, C, D	Yes	BIO-1, BIO-2a, BIO-2b, BIO-4a, BIO-4b, BIO-4c
BIO-9: Potential for Operation- and Maintenance-Related Mortality of California Tiger Salamander	B, Reduced B, C, D	Yes	BIO-1, BIO-2a, BIO-2b
BIO-10: Potential for Construction- and/or Operation- and Maintenance-Related Mortality of Western Spadefoot Toad	B, Reduced B, C, D	Yes	BIO-2a, BIO-2b
BIO-11: Potential for Construction- and/or Operation- and Maintenance-Related Effects on Blunt-Nosed Leopard Lizard	B, Reduced B, C, D	Yes	BIO-1, BIO-5, BIO-5a, BIO-5b, BIO-5c
BIO-12: Potential for Construction- and/or Operation- and Maintenance-Related Mortality of California Horned Lizard	B, Reduced B, C, D	No	

BIO-13: Potential for Construction- and/or Operation- and Maintenance-Related Mortality of Silvery Legless Lizard	B, Reduced B, C, D	No	
BIO-14: Potential for Operation- and Maintenance-Related Harm and Harassment of Giant Garter Snake	B, Reduced B, C, D	No	
BIO-15: Potential for Construction-Related Disturbance of Nesting Swainson's Hawk and White-Tailed Kite	B, Reduced B, C, D	Yes	BIO-6
BIO-16: Potential Loss of Foraging Area for Greater Sandhill Crane, Golden Eagle, Ferruginous Hawk, Prairie Falcon, Merlin, Mountain Plover, Long-Billed Curlew, and Short-Eared Owl	B, Reduced B, C, D	No	
BIO-17: Potential for Construction-Related Mortality of Western Burrowing Owl	B, Reduced B, C, D	Yes	BIO-1, BIO-7
BIO-18: Potential for Operation-Related Mortality of Western Burrowing Owl	B, Reduced B, C, D	No	
BIO-19: Potential for Construction-Related Harm to Loggerhead Shrike	B, Reduced B, C, D	Yes	BIO-1
BIO-20: Potential for Construction-Related Foraging Habitat Loss for Tricolored Blackbird	B, Reduced B, C, D	No	
BIO-21: Potential for Effects on San Joaquin Kit Fox	B, Reduced B, C, D	Yes	BIO-1, BIO-8
BIO-22: Potential for Effects on Fresno Kangaroo Rat	B, Reduced B, C, D	Yes	BIO-9
BIO-23: Potential for Mortality of San Joaquin Pocket Mouse	B, Reduced B, C, D	No	
BIO 24: Potential Mortality of Sensitive Species during Construction	C, D	Yes	BIO-10
BIO-25: Potential for Entrainment of Anadromous Fish If Restored to the San Joaquin River	D	Yes	BIO-11
BIO-26: Result in a Cumulatively Considerable Loss of Grassland	Cumulative	Yes	BIO-11
BIO-27: Result in a Cumulatively Considerable Loss of Habitat for Endangered Species	Cumulative	Yes	BIO-1
Cultural Resources			
CR-1: Damage to or Destruction of Nine Historic Features on Madera Ranch through Construction of Recharge Basins	B, Reduced B, C, D	No	
CR-2: Physical Modifications of Gravelly Ford Canal (P-20-2402)	B, Reduced B, C, D	No	
CR-3: Physical Modifications of Historic Main No. 1, Main No. 2 and Section 8 Canal	B, Reduced B, C, D	No	
CR-4: Physical Modification of 24.2 Canal	B, Reduced B, C, D	No	
CR-5: Physical Disturbance of Currently Undiscovered Cultural Resources	B, Reduced B, C, D	Yes	CR-1

Environmental Justice			
EJ-1: Disproportionate effects on minority or low-income populations	B, Reduced B, C, D	No disproportionate effects on minority or low-income populations	
Geology, Soils, Seismicity, and Erosion			
GEO-1: Potential Exposure of People or Structures to Substantial Adverse Effects Resulting from Liquefaction	B, Reduced B, C, D	No	
GEO-2: Potential Subsidence Caused by Groundwater Overdraft	B, Reduced B, C, D	No	MROC
GEO-3: Potential Risks to Property Caused by Construction on an Expansive Soil	B, Reduced B, C, D	No	
GEO-4: Potential Loss of a Substantial Amount of Topsoil from Land Grading Operations	B, Reduced B, C, D	No	
GEO-5: Increase in Wind and Water Erosion Rates during and Shortly after Construction	B, Reduced B, C, D	No	
GEO-6: Increase in Long-Term Wind and Water Erosion Rates	B, Reduced B, C, D	Yes	GEO-1
GEO-7: Potential Destruction of a Unique Pedologic Feature	B, Reduced B, C, D	Yes	BIO-1
GEO-8: Potential Soil Salinization from Elevated Groundwater Levels	B, Reduced B, C, D	No	
GEO-9: Potential Destruction of a Sensitive Paleontological Resource	B, Reduced B, C, D	Yes	GEO-2
Global Climate			
CC-1: Increased GHG Emissions during Construction	B, Reduced B	No	AQ-1, AQ-2
CC-1: Increased GHG Emissions during Construction	C, D, Cumulative	Yes	AQ-1, AQ-2
CC-2: Increase in GHG Emissions as a Result of Operation and Maintenance	B, Reduced B, C, D	Yes	AQ-3
CC-3: Secondary Emissions at Power Plants	B, Reduced B, C, D, Cumulative	No	
Growth-Inducing Effects			
GI-1: Inducement of Growth Attributable to Municipal and Industrial Participation in Water Bank	B, Reduced B, C, D	No	

Hazards, Public Health and Safety			
PHS-1: Potential Creation of a Public Hazard from Risk of Drowning	B, Reduced B, C, D, Cumulative	Yes	PHS-1a
PHS-2: Potential Creation of a Public Hazard from Risk of Berm Failure	B, Reduced B, C, D, Cumulative	No	
PHS-3: Potential Creation of a Public Hazard from Risk of Wildland Fire	B, Reduced B, C, D	Yes	PHS-1b, PHS-1b
PHS-4: Potential for Increase in Adult Mosquito Populations	B, Reduced B,C, D	Yes	PHS-2
PHS-5: Potential Exposure or Disturbance of Hazardous Materials or Wastes	B, Reduced B, C, D	No	WQ-1b
Indian Trust Assets			
ITA-1: Indian Trust Assets (ITA) are legal interests in property held in trust by the U.S. for federally-recognized Indian tribes or individual Indians.	B, Reduced B, C, D	No	
Land Use			
LU-1: Conflict with Applicable Land Use Plans, Policies, or Regulations, Including Land Use Designations and Zoning Ordinances	B, Reduced B, C, D	No	
LU-2: Land Use/Operational Conflicts between Existing and Proposed Land Uses	B, Reduced B, C, D	No	
LU-3: Conflict with Recreational Land Uses	B, Reduced B, C, D	No	
Noise			
NOI-1: Exposure of Residences to Noise from Grading and Construction Activities	B, Reduced B, C, D	Yes	NOI-1
NOI-2: Exposure of Residences to Noise from Well Drilling Operations	B, Reduced B, C, D	Yes	NOI-2
NOI-3: Exposure of Residences to Noise from Operation of Engines at Wells	B, Reduced B, C, D	No	
NOI-4: Exposure of Residences to Noise from Operation of Engines at Lift Stations	B, Reduced B, C, D	Yes	NOI-4
Effect NOI-5: Exposure of Residences to Noise from Operation of Engines at Lift Stations	B, Reduced B, C, D	Yes	NOI-4
Public Services and Utilities			
PSU-1: Increased Demand for Utilities	B, Reduced B, C, D	No	
PSU-2: Potential Disruption of Emergency-Response Routes (Moderate)	B, Reduced B, C, D	Yes	PSU-1a, PSU-1b
PSU-3: Temporary Disruption of Irrigation Service as a Result of Construction	B, Reduced B, C, D	No	
Effects related to the disruption of emergency response routes within Madera County	Cumulative	Yes	PSU-2a, PSU-2b
Socioeconomics			
SE-1: Increase in Temporary Construction-Related Employment and Income in the Fresno Metropolitan Statistical Area	B, Reduced B, C, D	Beneficial	

SE-2: Increase in Permanent Employment and Income in the Local Area	B, Reduced B, C, D	Beneficial	
SE-3: Increase in Water Costs Influencing Agricultural Production	B, Reduced B, C, D	No	
SE-4: Reliability of Water Supply on Changes in Employment and Income in the Local Area because of Increased Water Supply Reliability	B, Reduced B, C, D	Beneficial	
Traffic			
TRAF-1: Temporary Construction-Related Increase in Traffic Volumes on Local and Regional Roadways	B, Reduced B, C, D	No	
TRAF-2: Potential Increase in Construction-Related Traffic Volume Delay and Hazard on Local and Regional Roadways	B, Reduced B, C, D	Yes	PSU-1b
TRAF-3: Potential Damage to the Roadway Surface during Construction	B, Reduced B, C, D	Yes	TRAF-1
TRAF-4: Potential Increase in the Demand for Parking Space at the Construction Site(s)	B, Reduced B, C, D	No	
Water Resources			
WQ-1: Degradation of Water Quality Resulting from Construction Runoff	B, Reduced B, C, D	Yes	WQ-1a, WQ-1b
WQ-2: Water Quality Effects from Construction-Related Dewatering	B, Reduced B, C, D	Yes	WQ-2
WQ-3: Potential Effects on Groundwater or Surface Water Quality from Recharge or Recovery Operations	B, Reduced B, C, D, Cumulative	No	MOCP, MROC
WQ-4: Potential Soil Salinization from Elevated Groundwater Levels (also in Section 3.6, *Geology*)	B, Reduced B, C, D	No	
WQ-5: Potential Erosion Attributable to Reversal of Flows in 24.2 Canal and Cottonwood Creek/Main No. 2 Canal	B, Reduced B, C, Cumulative	Yes	MOCP, MROC, WQ-1a, WQ-1b, WQ-2
WQ-6: Potential Erosion Attributable to Reversal of Flows in Gravelly Ford Canal	D, Cumulative	No	MOCP, MROC
Water Supply			
WS-1: Changes in Groundwater Supplies or Overdraft Rates in Madera County	B, Reduced B, C, D	Beneficial	
WS-2: Substantial Effects on Surrounding Groundwater Wells as a Result of Recovery Operations	B, Reduced B, C, D, Cumulative	No	MOCP, MROC
WS-3: Substantially Alter the Existing Drainage Pattern or Contribute to Existing Local or Regional Uncontrolled Flows	B, Reduced B, C, D, Cumulative	No	MOCP, MROC
WS-4: Adverse Effects on the Area of Origin of Water from Amendments to Existing Water Rights	B, Reduced B, C, D	No	
WS-5: Reduced Surface Water Availability in Madera County or the Area of Origin	B, Reduced B, C	No	
WS-6: Water Supply Reliability Improvement in Dry Years	B, Reduced B, C, D	Beneficial	

WS-7: Adverse Effects on the Area of Origin of Water from Amendments to Existing Water Rights	D	No	
WS-8: Reduced Surface Water Availability in Madera County or the Area of Origin	D, Cumulative	No	
Wetlands			
WET-1: Permanent Removal of Vernal Pools and Alkali Rain Pools during Construction, Operation, and Maintenance	B, Reduced B, C, D	Yes	BIO-2a, BIO-2b
WET-2: Other Wetland Effects during Construction, Operation, and Maintenance	B, Reduced B, C, D	No	
WET-3: Cumulative Loss of Wetlands	Cumulative		

MOCP = Monitoring and Operational Constraint Plan (Appendix D)
MROC = Madera Ranch Oversight Committee

Section 1 Introduction

For any proposed major Federal action, Federal agencies must comply with the National Environmental Policy Act (NEPA), including full disclosure of potential direct, indirect and cumulative impacts as well as avoidance, minimization and mitigation measures in response to those impacts. This Final Environmental Impact Statement (EIS) satisfies the requirements for compliance with NEPA. NEPA requires the federal government to use all practical means and measures, consistent with other essential considerations of national policy, to promote a healthy human environment. It establishes policy, sets goals, and provides means for carrying out the policy. NEPA encourages the wise use of natural resources by requiring that environmental factors be considered in federal agency decision-making. NEPA also enables the public, private organizations, state and local agencies, and Native American tribal governments to be involved in and informed about the decision-making process.

This Final EIS has been completed for compliance with NEPA by the Department of Interior, Bureau of Reclamation (Reclamation) as the Federal lead agency for the Madera Irrigation District (MID) Water Supply Enhancement Project (WSEP) in Madera County, California. This Final EIS is an informational document that must be used by Reclamation when considering a decision on the MID WSEP Proposed Action or an alternative. Reclamation's NEPA process involves circulation of the Final EIS for 30 days prior to issuing a Record of Decision (ROD) and taking action. The ROD will describe the decision, the alternatives considered, the environmentally preferable alternative, relevant factors considered in the decision, and mitigation and monitoring requirements.

Reclamation's action relevant to the WSEP is to approve the banking of MID Central Valley Project (CVP) water outside MID's service area in the proposed Madera Ranch WSEP, and the alteration of the 24.2 Canal, a Reclamation-owned facility, as proposed by MID and described in Section 2 of this document. Reclamation owns and operates the CVP, a system of 20 reservoirs and more than 500 miles of major canals and aqueducts. The CVP includes Millerton Lake, contained by the Friant Dam on the San Joaquin River, which provides a portion of MID's water supply.

The Draft EIS for the MID WSEP was distributed for public review and comment on July 24, 2009. This Final EIS includes response to comments received on the Draft EIS in accordance with 40 Code of Federal Regulations (CFR) 1503.4. This Final EIS also discusses an alternative not discussed in the Draft EIS known as the Reduced Alternative B which has been selected as the preferred alternative, also referred to as the Proposed Action. Reduced Alternative B represents a scaled-back version of Alternative B that uses fewer swales in order to minimize effects to vernal pools and limits the number of recharge basins to the number needed for the project to be practicable. It is included in the FEIS as a revision to Alternative B to allow the public to see how the project has been modified, demonstrate how effects have been reduced, and facilitate the Corps use of this document in their permitting of the project.

In accordance with 40 CFR 1501.6, the lead Federal agency shall request that any other Federal agency which has jurisdiction by law be a cooperating agency. In addition, the lead Federal agency will collaborate to the fullest extent possible, with all cooperating agencies concerning issues relating to their jurisdiction and special expertise. To meet this requirement, Reclamation invited and received assistance from the U.S. Fish and Wildlife Service (USFWS) and the U.S. Army Corps of Engineers (Corps) as cooperating agencies. Reclamation provided the Draft EIS to the cooperating agencies for their review and assistance. These agencies will also be provided the Final EIS before its circulation.

1.1 Background

MID encompasses an area of 128,292 acres and delivers water to its service area as part of the Hidden Unit (Fresno River) and Friant Division (San Joaquin River) Long-Term Water Supply contracts with Reclamation. MID operates and maintains a gravity irrigation distribution system of approximately 300 miles of open flow canal systems and 150 miles of pipelines. In addition to the services rendered to the lands within MID, the District conveys agricultural water to the Gravelly Ford Water District (GFWD). MID is also a member of the Madera-Chowchilla Water and Power Authority, which operates and maintains the Madera Canal under an agreement with Reclamation.

The vicinity of Madera Ranch west of the city of Madera, in Madera County, California has long been considered a viable area to operate a water bank because of the aquifer space availability, fast percolation rate, and other characteristics. Other entities have previously explored opportunities to develop a water bank in the area, but for reasons not relevant to this analysis, these proposals were not implemented. These previous efforts, however, presented opportunities from which to learn and were a basis for development of more viable options that ultimately have resulted in MID's current WSEP proposal. MID as the state lead agency approved the WSEP in accordance with the California Environmental Quality Act (CEQA) in September 2005, based on their Final Environmental Impact Report (EIR) (State Clearinghouse #2005031068).

At the time, there was no proposed Federal action. Reclamation commented on the Draft EIR, stating that once MID proposed a Federal action, Reclamation would need to complete and satisfy all NEPA and all other Federal requirements before approving any Federal action.

In November, 2010, MID also adopted its Supplemental EIR to address new information and changed circumstances since the WSEP was approved in 2005. The Supplemental EIR provided updated information on MID's water supply relevant to the San Joaquin River Restoration settlement; updated information and analysis of impacts regarding bank participants, including 10,000 acre-feet (AF) of municipal and industrial (M&I) water users and 10,000 AF of water allocated to environmental users; and updated information and analysis of impacts on biological resources and new mitigation measures to protect biological resources, including special-status species and sensitive natural communities.

The Draft EIS was initiated in response to MID's request that Reclamation approve the banking of MID CVP water outside MID's service area in the proposed WSEP, and the modification of the 24.2 Canal, a federal facility.

The Draft EIS evaluated the potential environmental impacts of the No Action Alternative; Banking CVP Water Outside of the MID Service Area Using Swales and Alteration of Reclamation-owned Facilities; Banking CVP Water Outside the MID Service Area without Swales and Alteration of Reclamation-owned Facilities; and Banking CVP Water Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal (no alteration of Reclamation-owned Facilities).

MID has been working toward securing federal funds to assist in the cost of purchasing Madera Ranch and construction of the WSEP. In March 2009, Omnibus Public Land Management Act of 2009 (Public Law 11-111; H.R. 146-308) became law. Section 9102 of the law includes the WSEP and thus, has been authorized by the U.S. Congress and is eligible for federal funding. MID is pursuing funding through the appropriations process. MID will continue to pursue additional federal grants.

1.2 Proposed Action

On completion of the Proposed Action MID would bank a portion of their CVP water from the San Joaquin and Fresno Rivers and other non-CVP water in the aquifer underlying Madera Ranch. Water would be banked in the aquifer, and 10% of the water would be left behind to reduce overdraft. The Proposed Action (Reduced Alternative B) would involve two phases. Phase 1 would involve constructing necessary delivery infrastructure improvements (except for the Section 8 canal southwest extension), using select natural swales for recharge (550 acres versus 700 acres as proposed under Alternative B), and installing approximately five soil berms to direct recharge flows. Phase 2 would involve constructing a limited number of recharge basins (323 acres versus up to 1,000 acres under Alternative B) and facilities for recovery of banked water.

Reclamation would approve banking of CVP water outside the MID service area and alteration of Reclamation-owned facilities. Similar to Alternative B, Reduced Alternative B may include funding by Reclamation, under the Omnibus Public Land Management Act of 2009, the Policy and Program Services, Challenge Grant Program: Recovery Act of 2009 Water Marketing and Efficiency Grants, or any other funding source. Regardless of whether this funding is acquired, the project components and associated effects would be the same. A complete description of the Reduced Alternative B can be found in Section 2.

1.3 Purpose and Need

Currently, farmers in MID's service area use a combination of groundwater and surface water. During dry years there is not adequate surface water to meet the water demand and groundwater pumping increases substantially. The amount of groundwater that has been pumped from the aquifer in the vicinity of Madera Ranch has exceeded the amount of water that has recharged the aquifer, resulting in groundwater overdraft. Even in wet years, the groundwater basin is in severe overdraft because groundwater pumping is steadily increasing for agricultural use as well as M&I use. This overdraft has caused the water table to decline and groundwater quality to degrade and has resulted in excess space in the aquifer that could be used to bank surface water.

In the vicinity of Madera Ranch, the water table has declined more than 90 feet over the last 60 years. These conditions have made it increasingly expensive for farmers to pump groundwater. Additionally, in many years, MID has been unable to deliver sufficient surface water to farmers because water is available primarily during the early months of the year when irrigation demand is low, and often water is available only for short periods of time during the growing season.

The purpose of the proposed Federal action is to:

- enhance water supply reliability and flexibility by using the excess aquifer space for surface water storage (water banking);
- reduce existing and future aquifer overdraft;
- reduce groundwater pumping costs;
- increase groundwater quality;
- encourage conjunctive use in the region as a means toward regional self-sufficiency.

1.4 Applicable Regulatory Requirements and Required Coordination

This EIS is intended to fulfill the requirements of NEPA (42 United States Code [U.S.C.] §§ 4321-4370d) and the following statutes:

- Bald and Golden Eagle Protection Act (BGEPA), 16 U.S.C. §§ 668-668d, June 8, 1940, as amended 1959, 1962, 1972, and 1978.
- Clean Air Act (CAA), as amended, 42 U.S.C. §§ 7401-7671p, including 1990 General Conformity Rule;
- Clean Water Act (CWA), 33 U.S.C. §§ 1251-1387;
- Endangered Species Act (ESA), 16 U.S.C. §§ 1531-1544;
- Executive Order (EO) 11988 – Floodplain Management
- EO 11990 – Protection of Wetlands;
- EO 13007 – Indian Sacred Sites
- EO 13112 – Invasive Species; and
- EO 13186 – Migratory Birds
- EO 12898 – Environmental Justice;
- Farmland Protection Policy Act
- Federal Flood Insurance Program
- Memoranda on Farmland Preservation
- Migratory Bird Treaty Act (MBTA), 16 U.S.C. § 703 et seq.;
- National Historic Preservation Act (NHPA), 16 U.S.C.§§ 470-470x-6;

1.5 Public Involvement

- Reclamation published a Notice of Intent to prepare an EIS for the MID WSEP Proposed Action in the *Federal Register* on September 28, 2007.
- Reclamation held scoping meetings on October 22 and October 29, 2007 at MIDs offices. Before the meetings, public notices were posted at MID's offices and published in the *Madera Tribune* and the *Fresno Bee* announcing the time, date, location and purpose of the meetings. Each scoping meeting included an overview of the meeting's purpose, the proposed project and alternatives, potentially significant environmental issues, and opportunities for future public involvement.
- Pursuant to NEPA, the Draft EIS was made available for a 60-day public review period from July 24, 2009 to September 25, 2009. A notice of availability of the Draft EIS was published in the *Federal Register* July 27, 2009.
- To provide the public with opportunities to submit verbal and written comments on the Draft EIS, a public meeting was held during the Draft EIS circulation period at the MID Office, 12152 Road 28¼, Madera, California on August 27, 2009. The public comment period on the Draft EIS closed September 25, 2009. Written comments were received from two federal agencies, three state agencies, and four other entities.
- NEPA requires agencies to respond to comments on the Draft EIS that are received during the public comment period (President's Council on Environmental Quality (CEQ) Regulations for Implementing NEPA Section 1503.4). This document has been prepared pursuant to these requirements. Reclamation has considered all the comments received on the Draft EIS and has incorporated changes to Proposed Action based on comments received. Changes are denoted by a line on the right side of the document.

Details for the public outreach process are described in Section 4.

1.6 Regulatory Requirements

Permits and approvals would be required for the Proposed Action from a number of agencies as summarized in Table 1-1.

Table 1-1 Permits/Approvals Required

Agency	Permit/Approval
U.S. Army Corps of Engineers	Section 404 of the CWA permit
U.S. Fish and Wildlife Service	Section 7 of the ESA consultation
Bureau of Reclamation	MP620 permit (a Reclamation Mid-Pacific Region-specific permit issued for additions or alterations to Reclamation-owned conveyance and distribution facilities)
State Historic Preservation Office	Section 106 of the NHPA review
Regional Water Quality Control Board	Section 401 of the CWA certification; General Permit for Storm Water Discharges Associated with Construction Activity (CWA Section 402)
California Department of Fish and Game	Streambed Alteration Permit

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Section 2 Alternatives

2.1 Introduction

A Reduced Alternative B is included in this section. It is now the Proposed Action and is the result of a coordinated effort with the Corps, U.S. Environmental Protection Agency (EPA), USFWS, California Department of Fish and Game (DFG), MID and Reclamation to reduce overall environmental impacts. This alternative would use fewer swales and fewer basins than Alternative B.

This section provides a summary of the alternative screening process; a description of the Proposed Action, the three action alternatives, and the No Action Alternative. This chapter also provides a comparative evaluation of the potential environmental effects of the alternatives; and identifies the preferable alternative. The five alternatives analyzed in detail in this EIS are:

- Alternative A—No Action;
- Alternative B Banking water Outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities;
- Reduced Alternative B (Proposed Action)—Banking CVP water Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities;
- Alternative C—Banking CVP water Outside the MID Service Area Without Swales and Alteration of Reclamation-Owned Facilities; and
- Alternative D—Banking CVP water outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal (no alteration of Reclamation-Owned Facilities).

Table 2-1 Facility Components Associated with Project Alternatives

Component	Alternative B—Swales and Basins	Reduced Alternative B—Reduced Swales and Basins (Proposed Action)	Alternative C—Without Swales	Alternative D—Use of Gravelly Ford Canal
24.2 Canal Improvements	X	X	X	
Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection Upgrade	X	X	X	
Section 8 Canal Upgrades/Extensions	X	X	X (Excluding northern lateral)	X (Excluding new 1.55 mile segment in Section 13 and 14)
Gravelly Ford Canal Upgrade				X
Gravelly Ford Canal Sedimentation Basin and Flow Regulation Area	X	X	X	X
Cottonwood Creek Overflow Improvements	X	X	X	X
Reconditioning of existing ditches	X	X	X	X
Swales	X	X		X
Recharge Basins	X	X	X	
Section 8 Canal Southwestern Lateral Upgrade	X	X	X	X
Gravelly Ford Canal Section 21 Northern Lateral	X	X	X	X
Recharge Basins in Uplands	X	X	X	X
Recovery Wells	X	X	X	X
Recovery Pipelines and Electrical Facilities	X	X	X	X
Recovery Lift Stations	X	X	X	X

2.2 Alternative A – No Action

Under the No Action Alternative, MID would not bank MID CVP water (MID Long-Term Water Service Contract supplies from both the Friant Division and Hidden Unit on Madera Ranch) and Reclamation's delivery canals would not be enlarged (Figure 2-1). The No Action Alternative also excludes any funding by Reclamation, that would be available to the action alternatives, under the Omnibus Public Land Management Act of 2009, the Policy and Program Services, Challenge Grant Program: Recovery Act of 2009 Water Marketing and Efficiency Grants, or any other funding source.

MID may bank non-CVP water via a Warren Act contract with Reclamation on the property, and other limited on-site water banking and recovery facilities may be constructed if MID is able to find participants and funding to support these efforts. MID estimates that under the No Action Alternative, MID could only apply up to 5,000 AF per year (AF/year) of their own non-CVP water, and recovery operations likewise would be limited if Reclamation-owned facilities were not altered. The number of other participants and amount of water they could bring to the project is uncertain. Many participants, even if they bring their own supplies, also would have to obtain Reclamation's approval because banking of CVP water outside CVP contractor's service areas, transfers or exchanges of CVP water would be needed to deliver the water to the property and to recover it. Therefore, without the ability to bank MID CVP water outside MID's service area, the project likely would be infeasible for MID. MID's customers would be subject to continued water supply uncertainty and higher water costs because of a reduced supply and ongoing groundwater overdraft conditions.

If the Proposed Action does not proceed, MID likely would sell the property to other agricultural interests. MID has had numerous offers from prospective buyers, including dairy, orchard, and row crop farmers. The No Action conditions would continue to support agricultural activities. However, the type and extent of the activities are uncertain at this time. Future owners would be subject to compliance with all applicable Federal, State and local laws and regulations and any associated permits and/or approvals.

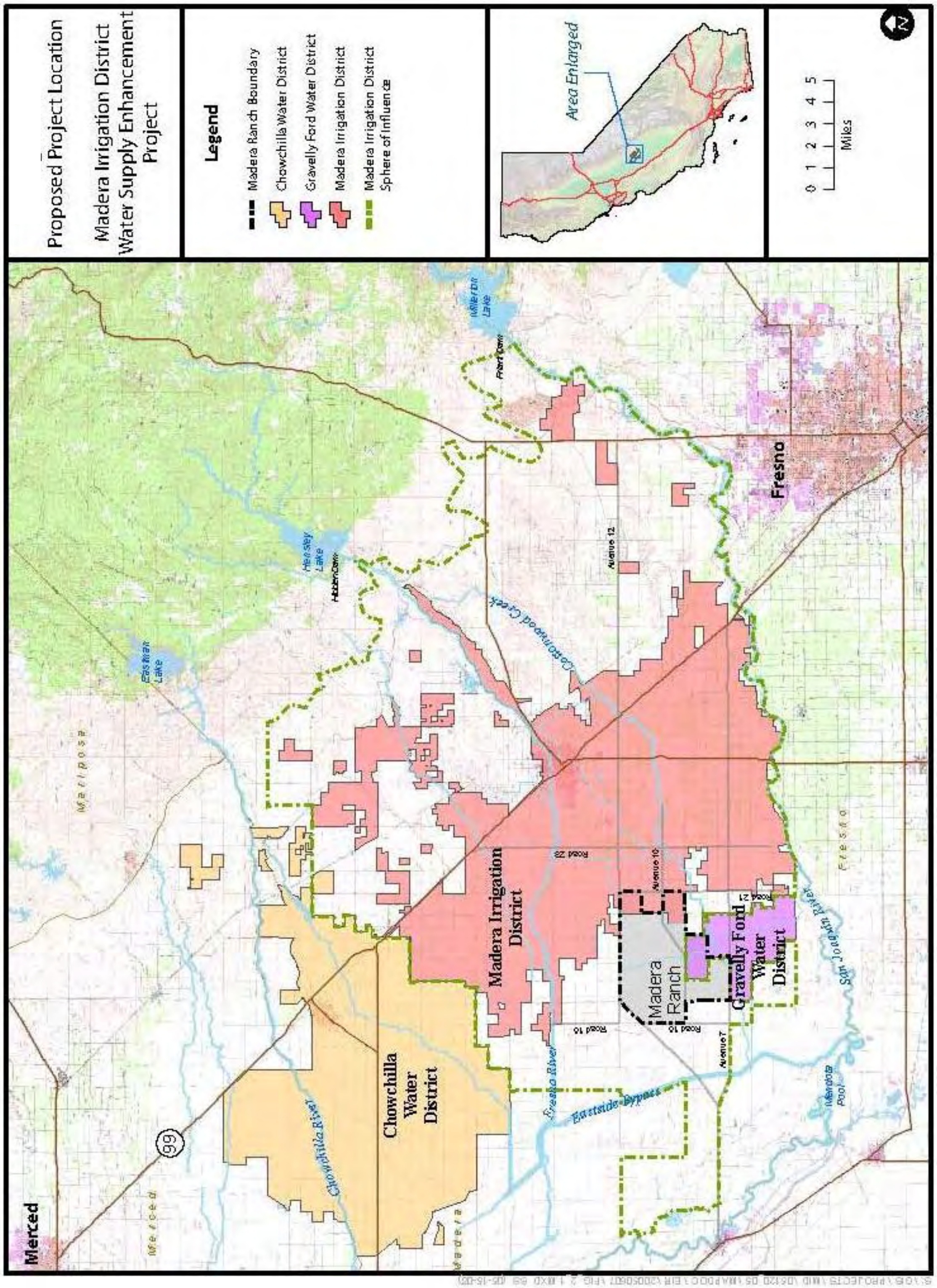

Figure 2-1 Proposed Project Location

2.3 Alternative B – Water Banking Outside MID Service Area Using Swales and Alteration of Reclamation-owned Facilities

Alternative B would be completed in two phases. Phase 1 would involve only recharge-related facilities. Phase 2 would involve supplemental recharge facilities and facilities for recovery of banked water. Reclamation would approve a total banking capacity of up to 250,000 AF of MID CVP water outside the MID service area and issuance of an MP-620 permit (a Reclamation Mid-Pacific Region-specific permit issued for additions or alterations to Reclamation-owned conveyance and distribution facilities) for alterations to Lateral 24.2. After alteration of the Reclamation-owned facilities (Lateral 24.2) and certain MID facilities, MID would be able to recharge and recover a maximum of 55,000 AF annually.

Alternative B also includes funding by Reclamation. MID has been working toward securing federal funds to assist in the cost of purchasing Madera Ranch and construction cost. In January 2009, the U.S. Congress passed the ―Omnibus Public Land Management Act of 2009" (Public Law 11-111; H.R. 146-308). Section 9102 of the Omnibus bill includes the ―Madera Water Supply Enhancement Project, California." Thus, the WSEP has been authorized by the U.S. Congress and is eligible for federal funding in the next budget cycle, in 2011. MID is currently pursuing federal funding through the appropriations process. In addition, MID pursued a grant award through Reclamation's Policy and Program Services, Challenge Grant Program: Recovery Act of 2009 Water Marketing and Efficiency Grants. The grant was not funded. Alternative B components and associated effects would be the same under various funding scenarios.

2.3.1 Phase 1

MID would implement Phase 1 to increase the capacity of existing MID conveyance facilities to deliver water to Madera Ranch facilities. Phase 1 would use primarily natural swales as recharge areas. Phase 1 activities would involve:

- reconditioning and extension of canals to provide at least 200 cubic feet per second (cfs) of conveyance capacity into Madera Ranch;
- construction of approximately 55 acres of recharge basins on current agricultural land to regulate flow, remove sediment, and provide some recharge;
- application of recharge flows to approximately 700 acres of swales; and
- integration of approximately 2,600 acres of Madera Ranch row crops and vineyards into an in-lieu recharge program in which surface water periodically would be served in lieu of groundwater pumping subject to approval by the Madera Ranch Oversight Committee (MROC).

Diversion and Conveyance Facilities

Figure 2-2 depicts the locations of existing canals in the vicinity of Madera Ranch.

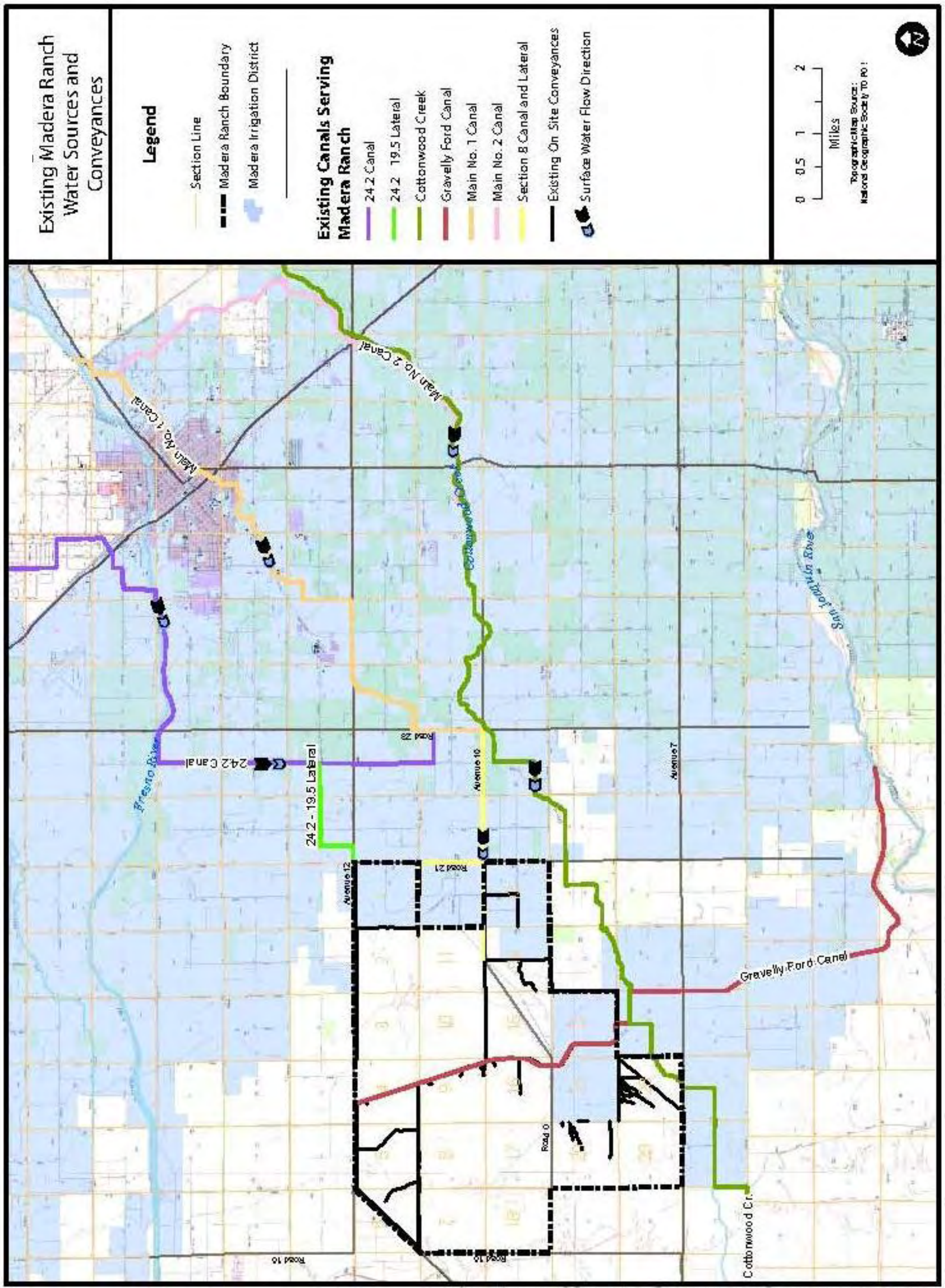

Figure 2-2 Existing Madera Ranch Water Sources and Conveyances

Upgrades to Existing Canals

During Phase 1, MID would upgrade canals to enable gravity delivery of at least 200 cfs into Madera Ranch. Upstream portions of Cottonwood Creek, the 24.2 Canal and the Main No. 1 Canal collectively provide more than 200 cfs of gravity feed conveyance capacity above MID's normal service needs during nonpeak irrigation months, and lesser amounts of capacity during peak irrigation months. However, the portions of these conveyances and the Section 8 Canal within two miles of the ranch are undersized, causing a bottleneck such that the capacity to deliver water to the ranch is less than 100 cfs. Specifically, the confluence of Cottonwood Creek, the Main No. 1 Canal, and the Section 8 Canal, approximately two miles east of the ranch, has a capacity of less than 100 cfs. In addition, the Section 8 Canal running from this confluence into the ranch has a capacity of less than 50 cfs, and the 24.2 Canal, 1.5 miles from the ranch, also has a capacity of less than 50 cfs and does not tie into the Section 8 Canal.

The following sections summarize how these and other conveyances would be upgraded to provide up to 200 cfs delivery capacity to and from Madera Ranch.

Reclamation Conveyance Facilities

MID would extend the Reclamation-owned earthen 24.2 Canal approximately 0.75 mile south to connect with the Section 8 Canal (Figure 2-3). The connector would be a buried pipeline, not an open canal. In addition, approximately 1.75 miles of the southern portion of the existing 24.2 Canal would be widened and deepened to accommodate 100 cfs of flow. In total, the extension pipeline and canal enlargement would involve moving approximately 36,000 cubic yards (cy) of soil. MID would acquire additional easements and fee title for canal expansion.

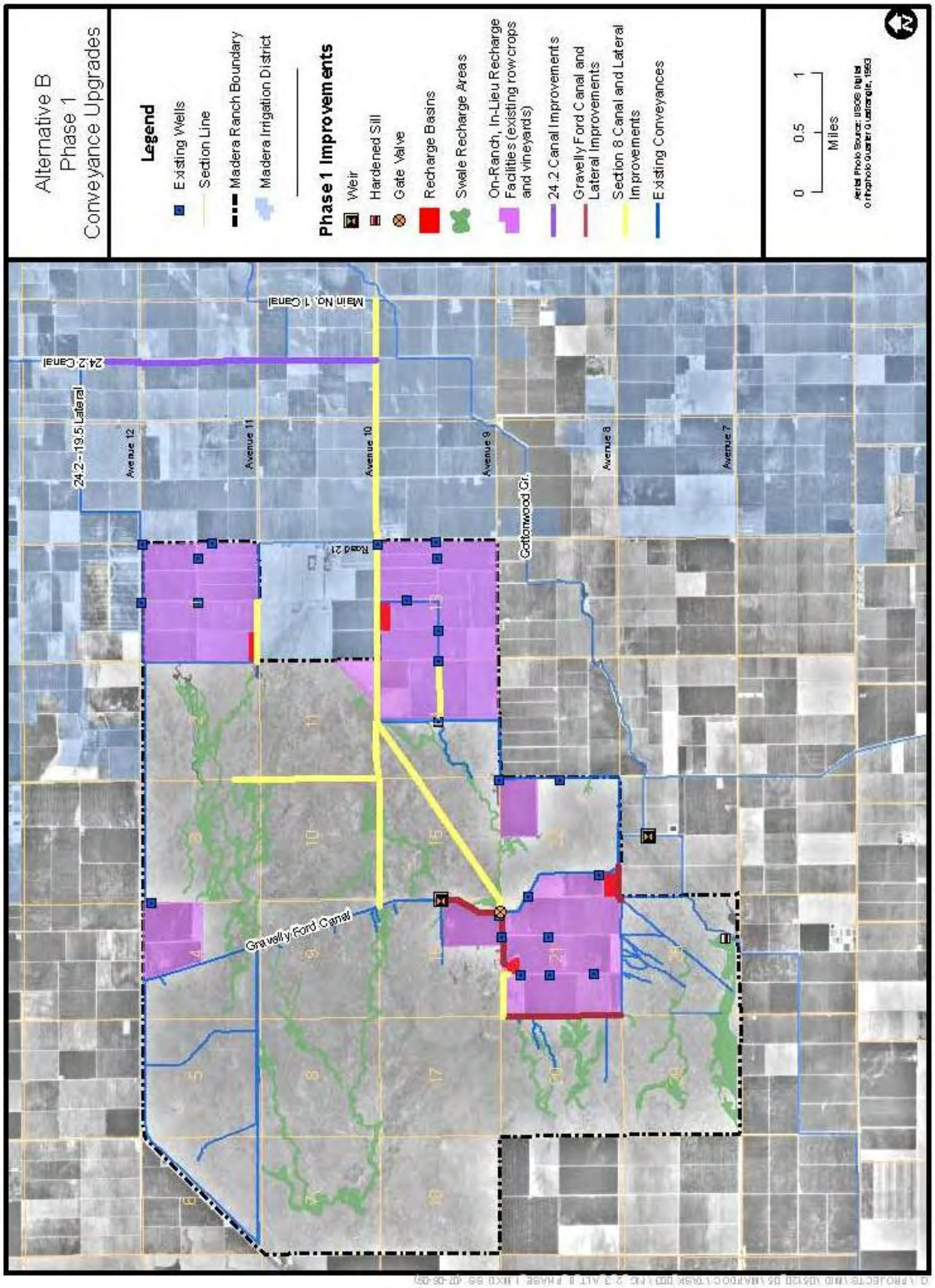

Figure 2-3 Alternative B Phase 1 Conveyance Upgrades

MID Conveyance Facilities

Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection Upgrade The existing connection between the Section 8 Canal (an earthen ditch built in the late 19th century), Cottonwood Creek, and Main No. 1 Canal would be widened and deepened to accommodate 100 cfs of flow. Only the connection would be widened; Cottonwood Creek would not be widened as its capacity is sufficient to meet the needs of the alternative. Work would be performed in an approximately 500-foot-long and 100-foot-wide area, requiring a temporary construction easement of 1.2 acres from neighboring landowners. No new permanent easements would be required.

Section 8 Canal Upgrade An approximately 1.75-mile segment of the earthen Section 8 Canal (from Road 23 to within approximately 0.25 mile of the Madera Ranch boundary at Road 21) would be reconstructed to expand from one-way, 50-cfs capacity to two-way (flat bottomed), 200-cfs capacity (Figure 2-3). The 1.75-mile segment of the canal from 0.25 mile east of the ranch, along the north side of Section 13 and to the western edge of ranch row crop land on the north side of Section 14, would be replaced with an approximately 1.75-mile-long, 84-inch reinforced concrete pipe (RCP), 200-cfs (two-way) pipeline placed within the channel of the existing canal.

During construction, Avenue 10 would be closed temporarily (local traffic only) to allow work on the canal. To expand the canal, an additional 40-foot corridor would be required, for a total of 8.9 acres of easement or fee simple ownership. The last 0.25 mile of the west end of the canal off-ranch would be carried in concrete pipe buried in the existing canal such that additional right-of-way would not be needed. A 40-foot-wide temporary construction easement may be required for this last 0.25 mile off-ranch (resulting in an easement of 1.2 acres). In total, this reconstruction involves moving approximately 76,000 cy of soil.

Section 8 Canal Western Extension A new, approximately 1.55-mile-long, 50 to 60-cfs earthen ditch would be constructed within a paved road in Sections 14 and 15 from the new Section 8 Canal pipeline to the Gravelly Ford Canal (GF Canal). The ditch would be constructed within the existing leveled shoulder (Figure 2-3). In total, this construction involves moving approximately 18,000 cy of soil.

Section 8 Canal Southwestern Extension Sections 14 and 15 are bisected diagonally by a 30- to 40-foot-wide, dirt farm road that was previously a ditch. A new approximately 1.8-mile-long, 20-cfs earthen ditch would be constructed from the new Section 8 Canal pipeline, along the shoulder of this road and to the GF Canal (Figure 2-3).

Section 8 Canal Northern Extension Sections 10 and 11 are divided by a 20- to 40-foot-wide dirt farm road bordered by the remnants of a ditch. A new approximately 1.2-mile-long, 20- to 50-cfs earthen ditch would be constructed along the alignment of the old ditch (Figure 2-3). In total, this construction involves moving approximately 14,000 cy of soil.

Section 8 Canal Section 14 Lateral Extension An existing Section 8 Canal lateral (20 cfs) that flows across Section 13 would be extended approximately 0.5 mile across Section 14 (Figure 2-

3). All work would be performed along the edge of row crop land. In total, this construction involves moving approximately 2,800 cy of soil.

Section 8 Canal Section 1 Lateral Extension An existing Section 8 Canal lateral (20 cfs) that flows east-west along the southern side of Section 1 would be extended approximately 0.5 mile to the southwestern corner of Section 1 (Figure 2-3). All work would be performed along the edge of row crop land.

Gravelly Ford Canal Sedimentation Basin and Flow Regulation Area With GFWD's permission, an approximately 3,000-foot-long segment of the GF Canal on the southeastern side of Section 16 would be equipped with a weir/control structure on the north side to allow use of the channel as a combined recharge area, sedimentation basin, and flow regulation area.

Gravelly Ford Canal Flow Control Weir at Cottonwood Creek With GFWD's permission, a new weir would be installed on the GF Canal approximately 1,000 feet south of Section 22 where the canal intersects and shares a channel with Cottonwood Creek. All work would be performed in the existing artificial channel and on adjacent farm roads.

Gravelly Ford Canal Section 21 Northern Lateral A new approximately 0.45-mile-long, 20- to 50-cfs earthen ditch would be constructed along the northern side of Section 21 from the GF Canal to a Phase 1 recharge basin located on farmland (Figure 2-3).

Gravelly Ford Canal Section 21 Western Lateral A new approximately 1-mile-long north/south canal would be constructed along the western side of Section 21 off of an existing 20- to 50-cfs earthen ditch bordering the southern side of the section. The new canal would be constructed on the shoulder of a dirt farm road bordering row crop land in Section 21 (Figure 2-3).

Gravelly Ford Canal Section 22 Southern Lateral A new approximately 0.28-mile-long, 20- to 50-cfs earthen ditch would be constructed along the southern side of Section 22 from the GF Canal to an existing ditch (Figure 2-3).

Cottonwood Creek Overflow Improvements A hardened sill (compacted or armored material with low potential for erosion) would be constructed on the existing Cottonwood Creek berm to protect the berm and to accommodate flow measurements. Sections 28 and 29 are inundated by Cottonwood Creek uncontrolled flows regularly during wet springs. These uncontrolled flows generally are prevented from flowing onto Avenue 7 by an earthen berm that runs along the southern boundary of Section 28 and north along the western boundary of Section 29.

Reconditioning of Existing Canals and Ditches Reconditioning would involve reconditioning GF Canal (described below), replacement of turnout gates (described below), brush removal, repair of berms that have been worn down over time, reconstruction of segments that have been filled by recent farm operations, and installation of farm road crossings as required.

Gravelly Ford Canal GF Canal is an earth-lined flat-bottom channel that conveys irrigation water from the San Joaquin River to Madera Ranch. Project elements affecting GF Canal include:

- Construction of a new weir structure and lift station (GF Canal sedimentation basin and flow regulation area as described above);
- Grading approximately 2.6 miles of the canal back to original design contour and capacity;
- Installing approximately three to five new turnouts;
- Replacing approximately two to three old turnouts; and
- Installing one flow monitoring station.

Gravelly Ford Canal Reconditioning GF Canal would be reconditioned north of the new weir and lift station to Avenue 12 (2.6 miles). Material that has eroded from the banks and settled in the bottom of the canal would be used to reform the banks of the canal. A grader and scraper would be used in the canal bottom to recontour the canal. Approximately 16,000 cy of dirt would be moved to reshape the existing berms of the canal.

Gravelly Ford Turnouts Approximately two new east berm turnouts would be installed to deliver water into the recharge areas. Three west berm turnouts would be replaced and three new west berm turnouts would be constructed (one to a recharge basin in agricultural lands, one gate structure to a new lateral canal system constructed in uplands, and one to an upland recharge areas). A flow monitoring station would also be installed. Each turnout is approximately 3-feet wide by 6-feet long by 6-feet tall and is/would be buried in the existing banks of the canal. The turnouts are constructed off-site at MID headquarters. Construction of the turnouts would require excavating approximately 32 cy of soil and the addition of 3 cy of fill material to install a gate and compact the soil adjacent to it.

Recharge Facilities

Recharge Basins Phase 1 would involve construction of approximately 55 acres of basins, approximately two basins that are 1,100 feet square, as shown in Figure 2-3 on agricultural land in order to:

- help regulate flows,
- allow settling of sediments before application of water to swales, and
- provide some recharge capacity.

The preliminary locations of four Phase 1 recharge basins are entirely on current agricultural land in Sections 1, 13, 21, and 22. The basins would be designed with 1.5:1 to 2:1 interior side slopes and average depths of four to five feet and surrounded by low earthen dikes created from the dirt excavated from the basin. Construction of the Phase 1 recharge basins could involve the movement of approximately 444,000 cy of soil.

Swale Recharge Areas Alternative B would entail diversion of water into approximately 700 acres of swales. The water would be conveyed to Madera Ranch through the existing and upgraded MID conveyances and to the swales through the existing, rehabilitated, and new ditches described above. At the head of each swale, a manually operated farm turnout (equipped with a gate valve and totalizing flow meter) would be installed to regulate and measure the flow into each swale. Several turnouts currently exist on GF Canal and these would be replaced and several new ones would be added. Flows at each turnout, based on pilot studies, would be no greater than 20 cfs and would average five cfs at the turnout. Maximum overall flows would be around one cfs per acre of application. Locations of the swales anticipated to be used during Phase 1 are depicted on Figure 2-3.

In-Lieu Recharge Facilities Madera Ranch includes 2,666 acres of row crops and vineyards that are irrigated entirely by a system of 23 wells. MID would recondition existing turnouts and install new turnouts under the Alternative B canals, pipelines, and ditches to enable delivery of surface water to these fields in lieu of groundwater pumping (Madera Irrigation District 2008*)*.

These agricultural fields were purchased from MID in July 2008 by Grimmway Enterprises, Inc. Grimmway will continue to manage the property for agricultural uses. However, MID has retained rights to existing and future easements that would allow this Alternative to be implemented.

2.3.2 Phase 2

Phase 2 would expand the areas used to recharge, develop wells and piping to recover the banked water, and install pumps to deliver the recovered water as shown in Figures 2-4 and 2-5.

Phase 2 activities for recharge and recovery facilities would involve:

- additional upgrades to existing canals,
- construction of up to 1,000 acres of new on-site recharge basins and canals as required to supplement Phase 1 facilities and achieve 200 cfs of recharge capacity (if required),
- use of up to 15 existing wells for recovery,
- installation of up to 49 new wells and recovery pipelines (in phases over several years) to provide 200 cfs of recovery capacity, and
- installation of up to 12 lift stations on MID canals and one lift station on GF Canal (in phases over several years) to provide 200 cfs of pump-back capacity into the MID service area.

Upgrades to Existing Canals

Section 8 Canal Southwestern Lateral Upgrade The 20- to 50-cfs, Phase 1 earthen canal running diagonally across Sections 14 and 15 would be partially replaced with an approximately 1.75-mile-long, 72-inch to 84-inch RCP, 135- to 200-cfs (two-way) buried pipeline. The pipeline would extend from the Phase 1 Section 8 Canal upgrade (200-cfs pipeline) to the GF Canal beneath an existing 30- to 40-foot-wide dirt farm road (Figure 2-4).

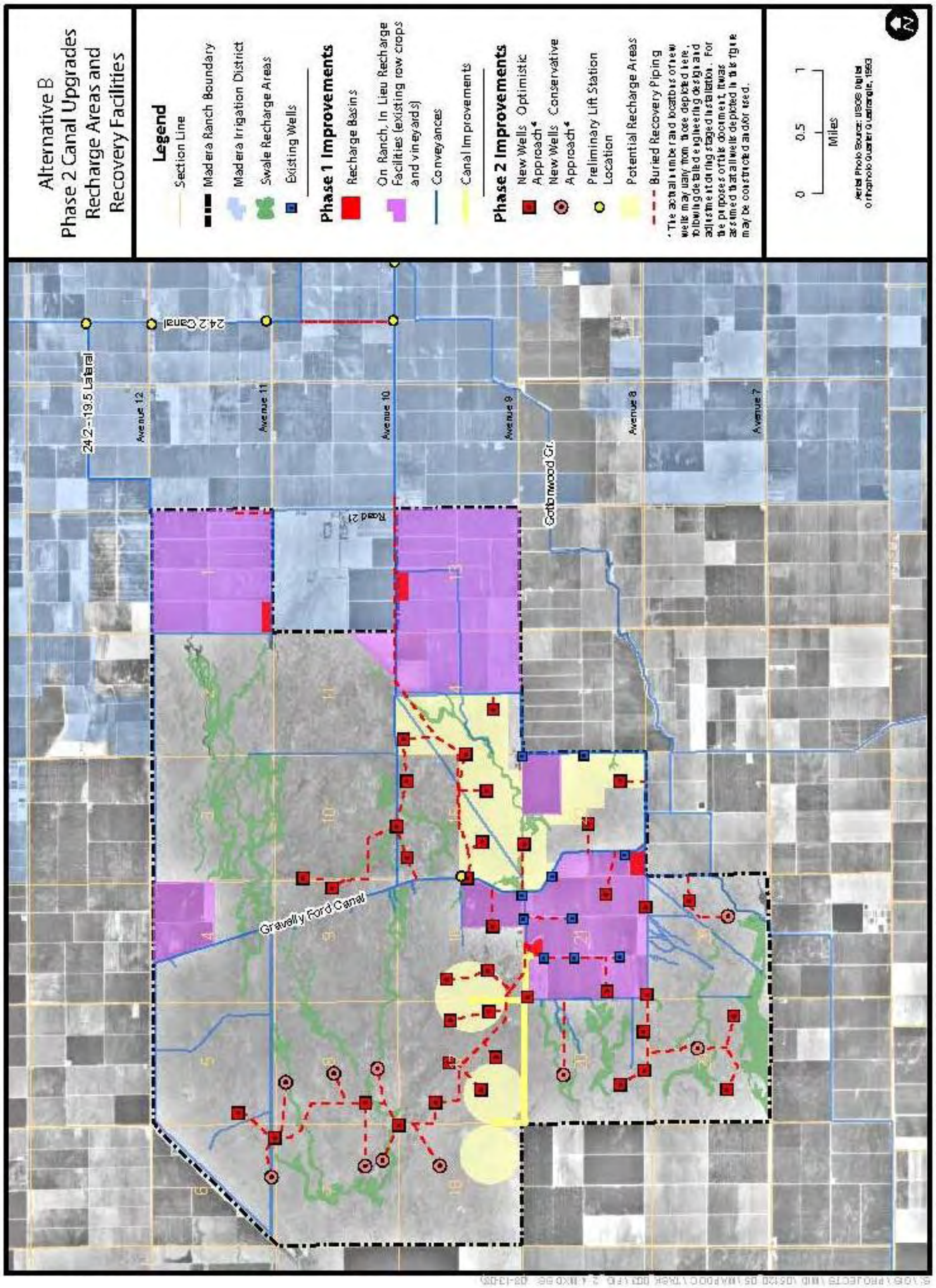

Figure 2-4 Alternative B Phase 2 Canal Upgrades, Recharge Areas, and Recovery Facilities

Gravelly Ford Canal Section 21 Northern Lateral The 0.45-mile-long Phase 1 ditch along the northern side of Section 21 would be replaced with an approximately 2.1-mile-long, 135-cfs, east-west earthen lateral canal along the north side of Sections 21 and 20 with two north-south sub-lateral canals running northward along the east and the west sides of Section 17.

Depending on the recharge basin acreage and construction methods up to 3.2 miles of 20- to 100-cfs earthen ditches would be constructed within the Phase 2 recharge basin area to distribute water into recharge areas.

Recharge Facilities

Depending on the performance of Phase 1 recharge facilities, up to approximately 1,000 acres of recharge basins may be constructed within a 1,300-acre area. Following pre-construction surveys as outlined in the Environmental Commitments, MID would begin construction of the basins. The following steps to construct recharge basins may occur, but would be dependent on final agency permits.

- *Stage 1:* Berming of recharge area boundaries along topographic contours using farm roads wherever possible and farm grading techniques, but no excavation (similar to unleveled rice fields).
- *Stage 2:* Deep ripping of corridors within the bermed areas, interspersed with corridors of undisturbed land.
- *Stage 3:* Excavation of basins varying from four to five feet deep.

The final number of recharge basins constructed and techniques summarized above is uncertain, and the highest estimated acreage is highly unlikely to be required. This EIS evaluates the potential effects associated with up to 1,000 acres of excavated basins. Recharge basins would be clustered in sets of three or four varying in size from 5 to 80 acres, with the first basin constructed in each set serving as both a settling and a recharge basin.

Construction of the recharge basins and internal routing ditches could involve the moving of up to approximately 7.7 million cy of soil. Basins would be designed with 1.5:1 to 2:1 interior side slopes and average depths of four to five feet. Low earthen dikes would be constructed around the recharge basins using excavated materials. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation.

Recovery Facilities

Recovery Wells Banked water would be recovered using up to 15 existing wells and approximately 49 new wells, as shown in Figure 2-4. Wells would be placed, whenever possible, at locations that could be accessed by existing farm roads and at least 0.25 mile within the interior of the Madera Ranch boundary. The wells would be connected via a manifold to a buried pipeline, and a canal and lift station system would deliver the water back to MID.

Recovery Pipelines and Electrical Facilities Up to 11.6 miles of 8-inch- to 60-inch-diameter polyvinyl chloride (PVC) to RCP buried recovery pipelines, as shown in Figure 2-4, would run from recovery wells to the GF Canal and the Section 8 Canal for delivery back to farmers. The recovery pipelines would be buried 2–3 feet beneath the ground surface. Electrical lines servicing the electrical well pumps would be placed in the same trenches as the recovery pipelines to minimize disturbance and to ensure that all electrical lines are placed below grade. The recovery pipelines would be constructed during the same stage of project development as the well construction.

Recovery Lift Stations The MID delivery system is currently all gravity feed from east to west. In order to deliver up to 200 cfs from the recovery wells to MID's customers, up to 13 lift stations would be required on the same conveyances used to deliver water into the water bank, as depicted in Figure 2-5.

- *Stage 1:* One lift station would be constructed along the GF Canal to pump water recovered from wells on the west side of Madera Ranch. Four lift stations with capacity stepping downward from approximately 100 cfs to 80 cfs would be constructed on the 24.2 Canal.
- *Stage 2:* Six lift stations with capacity stepping downward from approximately 100 cfs to 80 cfs would be constructed on Cottonwood Creek and Main No. 2 Canal.
- *Stage 3:* After several years of operation, up to two additional lift stations may be added to the upper reaches of the Main No. 2 Canal as dictated by the required additional level of delivery.

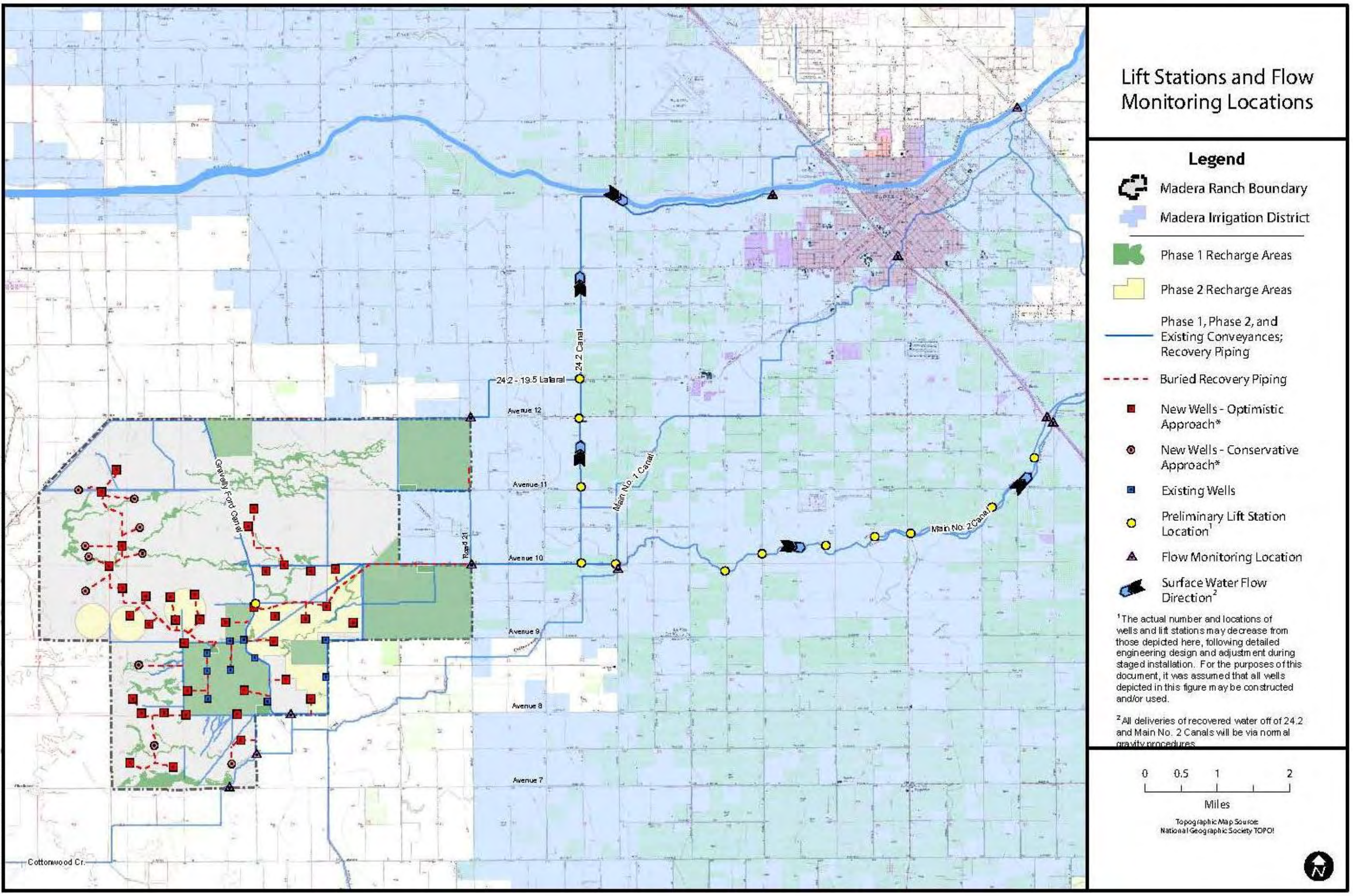

Figure 2-5 Lift Stations and Flow Monitoring Locations

2.3.3 Construction

The following construction activities would be similar for all action alternatives unless specified under a particular alternative.

Conveyance Facilities

Upgrade of Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection   The connection between the Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal would be widened and deepened to accommodate 100 cfs of flow. Upgrading the connection would involve the following steps:

1. Draining the canals.
2. Excavating mud or silt from the bottom of the canals, and storing the wet material on site or transporting it to a storage site.
3. Excavating the canals to a sufficient width and depth to provide adequate capacity.
4. Transporting the excavated material to Madera Ranch for use as fill required by other proposed construction.
5. Installing piping for road crossings.

Water to control fugitive dust emissions would be supplied by a water truck. An excavator and dump truck would be required. Approximately 12 people would be employed during the upgrade of the connection.

Section 8 Canal Upgrade   Phase 1 construction would involve installation of approximately 1.5 miles of 84-inch diameter RCP on Madera Ranch and an additional 0.25 mile of 84-inch RCP immediately east of Madera Ranch, all in the channel of the existing Section 8 Canal. Installation of the pipeline would involve the following steps.

1. Draining the canal.
2. Excavating mud or silt from the bottom of the canal, and storing the wet material on site, or transporting it to a storage site. The material would be used to backfill the excavation, if suitable. The stored mud or silt would not be placed on wetlands.
3. Excavating the canal to a sufficient depth to provide adequate cover over the RCP, and preparing the pipe bed.
4. Transporting the pipe to the site on low-bed trucks. Unloading and stringing the pipe together using a large crane or large forklift.
5. Setting the pipe into the trench with the crane.
6. Placing backfill around the pipe using front loaders and a bulldozer.
7. Compacting the material around the pipe with an excavator-mounted compacting wheel. Compacting material above the pipe with a vibrating sheepsfoot roller.
8. Finishing the grade over the pipe with a motor grader.
9. Crossing in an area with steep banks. Both crossings would also require Section 404 permits from the Corps.

Water to control fugitive dust emissions would be supplied by a water truck. A gang truck and two or more pickup trucks would be required during pipe laying. Approximately 12 people would be employed during the installation of the pipeline. Installation of the 84-inch RCP temporarily would affect an area of approximately 32 acres adjacent to farmland.

Off-Ranch Canal Expansion and Extension Several reaches of the Section 8 Canal (1.75 miles), the 24.2 Canal (1.75 miles), and the Main No. 1 Canal (500 feet) would need to be expanded to increase their capacities to 200 cfs, 100 cfs, and 100 cfs, respectively.

Canal expansion would employ methods, equipment, and labor similar to the conveyance upgrades discussed above (see Upgrade of Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection). Temporary construction activities would affect about 53 acres. Additionally, MID would extend the 24.2 Canal approximately 0.75 mile to the south through a new pipeline to connect with the Section 8 Canal. Canal extension would employ methods, equipment, and labor similar to canal construction and pipeline installation. Temporary construction effects associated with extension of the 24.2 Canal would affect about nine acres.

On-Ranch Canal Extensions Existing on-ranch canals would be extended to deliver water to the recharge areas. Approximately 7.5 miles of canals would be extended on Madera Ranch. Extending the canals would involve the following steps.

1. Excavating the canal using an excavator or a Briscoe ditching machine pulled by a tractor.
2. Placing fill material for the canal embankments. Every effort would be made to balance cut and fill so that no import of material is necessary. Spoil material can be placed in the embankments.
3. Compacting the embankments using a vibrating sheepsfoot roller.
4. Finishing canal and embankment shaping with a diesel-powered, rubber-tired Gradall and motor grader.

Moisture for compaction of embankments would be applied from a water truck. The water truck also would provide dust control. A gang truck and two or more pickup trucks would be required to support canal construction. Approximately 10 people would be employed during canal construction. The area temporarily affected by canal extension would be approximately 81 acres on Madera Ranch.

On-Ranch Canal Reconditioning A diesel-powered, rubber-tired Gradall excavator; a Briscoe ditching machine pulled by tractor; and a diesel-powered, rubber-tired backhoe/front end loader would be used for reconditioning ditches and cutting farm road crossings within Madera Ranch.

Weir Installation Two weirs would be installed on GF Canal. Construction of the weirs would involve the following steps.

1. Clearing and grubbing the site with a motor grader and backhoe.
2. Excavating for the structure with an excavator.
3. Constructing wooden forms for the structure. Installing reinforcing steel bars within the forms.

4. Placing concrete from ready-mix trucks. A concrete pump may be used if necessary. Finishing the concrete surfaces and applying curing compound. Allowing the concrete to cure. Removing the forms and repairing the surface as necessary.
5. Placing backfill around the structure with a front end loader. Compacting the backfill with hand whackers.
6. Finishing the grade with a motor grader.

A pickup truck and a flatbed truck would be required to haul materials during construction. Approximately five people would be employed during construction. The areas temporarily affected by construction would be about 1 acre.

Recharge Facilities

Recharge Swales (Phase 1) Phase 1 recharge swales would remain unaltered and would not be subject to any construction activities.

Construction of Recharge Basins (Phase 2) The following staging may occur, but would be dependent on final agency permits.

- *Stage 1:* Berming of recharge area boundaries along topographic contours and using farm roads wherever possible. These recharge areas would be constructed using graders that follow prestaked topographic contours to raise 1- to 3-foot-high berms around the downslope portions of areas ranging from five acres to 80 acres. Berm material would be obtained from an approximate 50-foot-wide corridor parallel to the interior toe of the berm. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation.
- *Stage 2:* Deep ripping of corridors within the bermed areas, interspersed with corridors of undisturbed land. This would be done to ensure deeper percolation is maximized during project operation.
- *Stage 3:* Excavation of basins varying from four to five feet deep. Because of the demonstrated permeability of soils at Madera Ranch, Stage 3 recharge basins are unlikely to be required. However, in the event these basins were used, they would be clustered in sets of three or four varying in size from five acres to 80 acres, with the first basin in each set serving as both a settling and a recharge basin. Basins would be designed with 1.5:1 to 2:1 interior side slopes and average depths of four to five feet. After excavation, each basin would be shallow-ripped or disked by construction equipment in order to break up compaction of the bottom soils in the recharge basin. Low earthen dikes would be constructed around the recharge basins using excavated materials. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation. Excess soil removed during excavation would be managed to ensure that top layers are stockpiled, excavated soils would be mounded between basins, and stockpiled topsoil would be placed on top of the soil pile.

It is estimated that Stage 3 recharge basins would be constructed using:

- three to 20 heavy diesel-powered scrapers (40- to 60-yard capacity);
- three to five 500-horsepower (hp) diesel-powered skip loaders;

- 15 to 30 heavy-duty, off-road-type trucks (60-yard capacity);
- three to five large, diesel-powered, crawler-type tractors; and
- three to five diesel-powered motor graders.

The final combination of the acreages and techniques summarized above is uncertain. However, as previously discussed, this EIS evaluates the potential effects associated with 1,000 acres of Stage 3 excavated basins.

Recovery Facilities

Recovery facilities include recovery wells, pipelines, and lift stations.

Construction of Recovery Wells The recovery wells would be constructed by drilling to a depth of approximately 300–320 feet below ground surface. The wells would be gravel-packed between the casings and bore holes to maximize efficiency. Construction techniques would involve drilling, flushing, development, and testing to maximize well efficiency and longevity. The screen opening size, screen length, and screen depth of each well would be determined in the field by a registered geologist.

Drill rigs would use portable steel mud pits rather than excavated pits to reduce effects on surrounding habitat. Drilling water would be trucked in to most drill sites and stored in portable tanks. Two small berms would be used to control accidental spills during drilling operations, as required by Occupational Safety and Health Administration. A small berm would be constructed with a small front loader around the perimeter of the 100-foot-by-100-foot temporary construction area. Another berm would be constructed around all drilling equipment, and the area inside the berms would be lined with tarps to contain accidental spills of fuels, lubricants, and drilling effluent. These berms would be constructed of local materials. After drilling is completed, all equipment and fluids would be disposed of in a lawful manner; the berms would be leveled, and the sites would be restored to near preconstruction condition.

Each new well would be equipped with a line-shaft-driven, deep-well turbine pump typical of agricultural pumps. Each wellhead would be fitted with an electric motor, controls, valves, and individual water meters and would be mounted on a concrete slab, approximately five feet by five feet, to stabilize and seal the well and provide a stable foundation for the motor, controls, and piping. The new pumps could be driven by 25- to 200-hp electric motors. Electricity would be supplied to the wells through underground electrical cable adjacent to the collection pipeline. A transformer, switchgear, and control cabinet would be constructed adjacent to each well on a concrete slab, approximately six feet by 14 feet. Each well would be fenced within an enclosure of approximately 600 square feet to allow most areas of Madera Ranch to continue to be grazed by cattle. Well maintenance is described in the Maintenance section.

Five of the existing wells to be used for recovery are currently powered by diesel engines, and nine of these wells are powered by electric motors. These operations could be changed so that all recovery wells could be powered by electric motors, but the assumption is that existing propane powered pumps could remain and that new pumps could be propane gas–powered. Installation of each well would temporarily affect an area of approximately one acre, and each facility would permanently affect about 0.1 acre.

Installation of Recovery Pipelines The recovery pipelines would be constructed by trenching rectangular ditches wide enough to lay the pipe. Trenching would be performed by backhoes, track hoes, or trenching machines. Soil would be temporarily sidecast within the construction corridor and pushed back into the trench once the pipeline is in place. Backfill would be compacted using a vibrating sheepsfoot roller. Piping would be of manufactured materials, such as PVC or polyethylene, with the exception of steel pipe at the wellheads and RCP for larger diameters approaching 60 inches. Pipeline installation would temporarily disturb about 140 acres.

Construction of Recovery Lift Stations Lift stations would consist of reinforced concrete check structures with pumping equipment to reverse flow. The gates would allow control of flows of surface water to Madera Ranch and would be closed to accommodate reverse flows when recovered water is being pumped back to MID's customers.

Construction of the structures would require excavation of the site, erection of forms, installation of steel reinforcement and embeds, placement of concrete, stripping of forms, concrete patching, placement of backfill around the structure, and compaction of the backfill. Material from the structural excavation would be used for backfill after being conditioned to attain the proper moisture content.

Discharge piping would be installed for connection to the pumps. The pump connection would be aboveground, and the discharge to the canal would be underground for discharge below the water level. A trench would be excavated for the buried portion of the piping. The pumps would require installation of structural steel beams and grating, mounting of the pumps and drivers, and installation of electrical wiring and controls.

Required equipment would include an excavator, a backhoe, a water truck, a pickup truck, vibrating plate compactors, concrete ready-mix trucks, a compressor, a generator, a boom truck or crane, and an electrician's truck. Labor would require, at various times, a superintendent, carpenters, steel workers, laborers, operators, and electricians. The maximum crew probably would not exceed 12 persons.

Lift stations would be constructed in three phases, requiring about 90 to 120 days for each phase. Each lift station would require a work area of about 0.25 acre that would be disturbed during construction. The final area occupied by the structure would be about 2,500 square feet. The total area permanently affected by the lift stations would be less than 1.2 acres.

Staging Areas

MID would use its existing off-ranch facilities for the long-term storage and maintenance of materials and equipment. However, Madera Ranch has a central headquarters area with equipment laydown areas and storage buildings. MID would use these facilities as needed to store equipment and materials that would be used to construct, maintain, and operate this Alternative.

Construction Traffic

The primary transportation corridors to Madera Ranch would be State Route (SR) 99, Avenue 7, and Avenue 12 (Figure 2-1). The majority of the vehicle trips generated by Alternative B most likely would originate in Madera and Fresno, proceeding up SR 99 to either the Avenue 7 or the Avenue 12 exit, then to Road 23, Road 21, and Avenue 10, where traffic would enter Madera Ranch.

2.3.4 Maintenance

Maintenance Corridors

The maintenance corridors would include new roads in the recharge basin area and areas with heavy disturbance, and unimproved routes in grassland areas. The maintenance corridors would be configured to take advantage of existing farm roads, fence lines, farmed areas, and recharge basin areas. Maintenance corridors through undisturbed grassland areas would not be graded or gravel-packed.

Diversion and Conveyance Facilities

Maintenance of the Section 8 Canal, Cottonwood Creek, the 24.2 Canal and Main No. 1 Canal would be consistent with maintenance of most water infrastructure in the San Joaquin Valley. Channels would require cleaning every several years. Each channel would be cleaned using mechanized dredging. The dredged material would be disposed of in a lawful manner. Cleaning would be scheduled during periods when the canal is not in operation. Banks of channels would be kept clear of brush and trees, and small mammal burrows would be filled to minimize erosion of the channel banks.

Maintenance of the on-ranch conveyance ditches and canals also would be consistent with that of most water infrastructure in the San Joaquin Valley. Pumps, gates, and appurtenances would be serviced when they are not operating to keep the system in top condition. The exterior canal slopes would be kept clear of large brush and trees, but grass and small shrubs would be acceptable as long as the root systems do not compromise the interior canal lining. Noxious weeds and brush would be removed to prevent them from becoming established on nearby cropland. Canals and ditches on MID property would be unlined but would be kept clear of vegetation. Mechanical removal and permitted herbicides would be used to control unwanted vegetation. Any evidence of small mammal burrows would be monitored and burrows filled in to reduce the possibility of damage, leakage, and potential collapse of canal banks. Maintenance roads parallel to the canals and ditches would have all-weather surfaces; vegetation would be controlled.

Access to canal bottoms would be by intermittent ramps that would allow mechanical equipment access into the canals for cleaning. Deeper sections of canals would be cleaned using small mechanical equipment such as rubber-tired front-end loaders or ―bobcats.” Materials removed from the canal bottoms would be disposed of by legal means, including spreading on farmland as allowed or on the maintenance areas of the groundwater bank property. Shallow sections of canals or ditches may be cleaned out using Gradall excavators that would work from access roads. The frequency of cleaning operations would be determined by what is necessary to maintain reasonable flow regimes in the canals.

Recharge Facilities

Recharge swales and basins would stand idle during dry years, when water is not available for banking. No maintenance would be performed in swales during these times, but recharge basins may be scarified as described below. During operation of recharge basins, it may be necessary to apply algaecide or other chemicals to keep vegetation in check and to minimize algae growth. Algaecides would not be used within natural swales used for recharge. Basin operation would require infrequent delivery of miscellaneous repair equipment, usually in smaller trucks such as non-semi, three-axle rigs. On average, after five years of actual use, basin bottoms would be scarified to remove the thin layer of low impermeable material that would develop over time. Other maintenance activities would be conducted as necessary.

Recovery Facilities

Recovery Wells Wells, meters, pumps, and appurtenances would be maintained during periods when recovery is not in progress to allow ready startup when a bank participant requests water. The wells are expected to run for up to five operating years before needing maintenance or repair. The well pumps are expected to operate for at least 10 years before requiring maintenance or repair. When a pump needs to be removed, a ―pump rig,” consisting of a truck-mounted boom designed to easily remove deep well pumps, would be brought in and backed up to the wellhead. The well discharge head and pump column, normally in 20-foot lengths, would be removed and ―laid by” the well on wood planking to keep them reasonably clean. The pump would be replaced with a new or refurbished pump by reversing the removal operation. The pump then would be taken to the shop for repair or overhaul. During operation, some fuels and lubricants may be transported to the site. Wells would be reworked on an average 20-year cycle.

Recovery Pipelines Nominal maintenance of recovery pipelines would be required. The anticipated life of recovery pipelines is approximately 50 years; however, in the event of a break in a pipeline or excessive leakage, segments of a pipeline would need to be replaced. Depending on the size and length of the segment to be replaced, the pipeline would be either mechanically or hand-excavated.

Maintenance Roads and Corridors Nominal maintenance on the maintenance roads and corridors would be required. The maintenance roads may require maintenance during wet winters if portions of the roads wash out or become impassable. To minimize effects on grassland habitat, no maintenance of the corridors in grassland areas is proposed.

2.3.5 Operations

Madera Ranch operations, including banking, water recovery, and maintenance to support banking and recovery, are described below, including measures to monitor potential effects on neighboring farmers and districts (adjacent stakeholders).

Water Banking

MID would bank a portion of its long-term water supply made available by contracts with Reclamation (Friant Division and Hidden Unit supplies), CVP uncontrolled flows provided under temporary contract and MID's pre-1914 non-CVP water rights supply. It is expected that average annual water available for banking would be approximately 20,000 AF (15,000 AF with river restoration) with wet years providing up to 55,000 AF (see the Water Supply Section for additional information). Water typically would be banked from mid-October through mid-April, depending on water-year type and availability.

Figure 2-6 illustrates the typical recharge season and historic deliveries. The upper part of the figure shows maximum Hidden Unit releases in relation to average Friant Division deliveries to MID, and indicates that off-season deliveries could occur and be used for recharge when water is available. Large amounts of water are unlikely to be banked during the summer because MID's system is being used to convey water to farmers. The lower part of the figure shows that based on historic deliveries, more than 45,000 AF was available less than 5% of the time; in May, for example, approximately 45,000 AF was available 5% of the time, 25,000 AF was available 70% of the time, and 18,000 AF was available 100% of the time. Water supply estimates based on the record from 1985 through 2007 indicate great variability in banking opportunities, ranging from less than 20,000 AF in 61% of years to more than 20,000 AF in 39% of years.

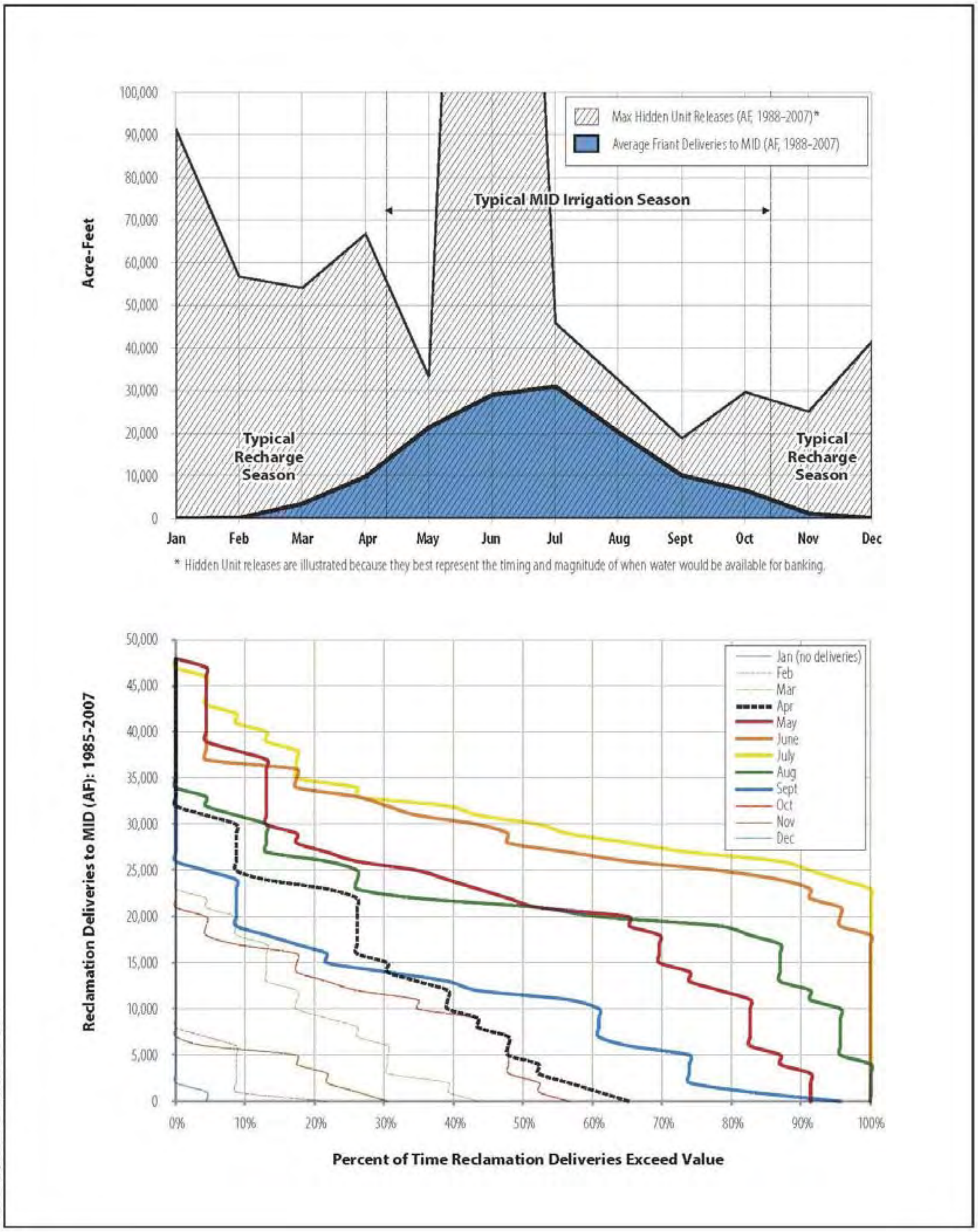

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Figure 2-6 Typical Recharge Season and Historic Deliveries

Water would be delivered into distribution ditches, swales, and recharge basins through the enlarged Section 8 Canal (converting to a pipeline within Madera Ranch), the 24.2-19.5 lateral, the GF Canal, and Cottonwood Creek. Parshall flumes and weirs would be installed in these conveyances to regulate and measure flows.

Upstream recharge basins would be used for sedimentation. Flows through ditches, swales, and basins would be regulated in accordance with monitoring and operating criteria designed to prevent overflows and unacceptably high water table elevations beneath adjoining properties. MID would control upstream, off-site flows to avoid spillage in the same manner that current water operations are conducted. Ditch riders would monitor the flow in each canal, ditch, swale, and recharge basin to ensure proper control of flows and to ensure that programmed water levels in the recharge areas are maintained. Spillage would be minimized through diligent observation of conditions in accordance with MID’s standard operating schedule.

Flows in the swales would be constrained by acreage (approximately 550 acres) and the canal’s capacity to deliver water to the swales. Water depths could range from several inches to several feet depending on the topography of the swales, percolation rates, and the amount of water being applied. Flows in the canals would be constrained by capacity, and recharge for banking in the canals, including GF Canal, would depend on the percolation rates. During water years with limited water available for banking, MID would use canals and selected swales to bank available supplies. The swales would be selected based on readily available canal delivery locations and other management needs. Flows to the recharge basins, should they be needed, would be similarly constrained by seasonal water availability and delivery capacity.

Reclamation worked with MID to determine the maximum area that would be inundated and discussed this approach with the USFWS, Corps, and DFG in February 2010. In general, when doing initial operations, MID would step up the flow into a swale in discrete increments (typically around 2-5 cfs per increment) and once the inundation for that flow has stabilized (typically within one day), MID would mark the wetted extent with global positioning system (GPS). MID would then step up to the next higher flow increment and repeat the process. MID followed this process in a pilot project until they reached the maximum wetted extent. These flow-versus-inundated acreage data pairs allowed MID to build a –rating curve” for a swale. This curve allowed MID to predict very accurately the wetted area given a certain flow. MID would then repeat the construction of the rating curves approximately two to three more times during a recharge season so that MID can observe how the swales perform over time. Because MID is stepping up from low to high flows, MID would be able to observe how each incremental segment of a swale contributes to or detracts from performance.

Monitoring and Operational Constraints Plan

Alternative B would recover no more than 90% of banked water, ensuring that there is a net gain by the aquifer. Recovered water would be delivered to farmers within MID, and potentially for M&I and environmental uses, ensuring that any deep percolation is recharged into the local aquifer system.

Madera Ranch Oversight Committee Adjacent property owners have expressed concern that water levels could rise and flood root zones during recharge events and that pumping costs might increase as the water table declines during recovery events. MID determined that modeled predictions would not provide sufficient security for adjacent stakeholders. Therefore, on April 17, 2006, the MID Board approved formation of the 10-member MROC composed of:

- the five MID board members;
- one elected board member from GFWD, as selected by the GFWD board;

- three independent members, representing the interests of surrounding landowners not within the service areas of MID or GFWD; and
- one County Supervisor.

The MROC would:

- ensure implementation of the Monitoring and Operational Constraints Program (MOCP) for Alternative B;
- protect adjacent landowners from unacceptable impacts by reviewing monitoring results and making recommendations for adjustments to operations if data suggest unacceptable impacts may occur;
- make recommendations for adjustment to the monitoring program as appropriate,
- prepare annual monitoring reports; and
- make available complete raw monitoring data to the Conservation Easement holder, the USFWS, the Corps, the DFG, and Reclamation within two weeks of obtaining the data from the MID. Provide the annual monitoring reports to these same five agencies as well as inform them within two weeks of any votes taken by the MROC, and the outcomes.

The MROC would meet monthly during recharge/recovery periods (usually winter/spring and summer, respectively) and quarterly during other periods when the facility is not in operation.

The MROC would implement the MOCP (Madera Irrigation District 2007) to ensure there are no unacceptable impacts on groundwater levels or quality. The draft MOCP includes the following components:

Water Level Monitoring MID would monitor water levels in on-site and off-site wells and adjust recharge operations to prevent off-site water levels from rising to within 30 feet of the ground surface. In the event that off-site water levels rise to within 30 feet of the ground surface, recharge operations would be halted and not be restarted until approved by the MROC. During recovery operations, MID would monitor water levels with operational adjustment, compensation, or provision of alternate sources of water in the event that water levels drop to unacceptable levels in off-site wells as a consequence of operations.

Water levels would be monitored in a network of wells that would include:

- recovery wells,
- wells near the Madera Ranch boundary, and
- select irrigation wells located at varying distances from Alternative B facilities.

The MROC would determine the numbers and locations of wells to be monitored. All wells installed only for monitoring purposes would be constructed within existing roads or lands already disturbed by other components of this Alternative (e.g., recharge basins).

The MROC would establish protocols to adjust operations and to avoid, minimize, or recommend compensation for adverse effects. Monitoring data collected during recharge and recovery would be interpreted using methods preapproved by the MROC to provide two levels of protection. First, data would be used in real time to adjust operations. Second, if, after adjusting operations, data indicate that off-site water levels would decline or rise (or have declined or risen) an unacceptable amount as a consequence of operations, the MROC would be immediately notified.

MROC would provide monthly raw data to the Corps and USFWS on request.

Water Quality Monitoring This Alternative primarily would convey and recharge water originating from Millerton Lake (Friant Division water) with lesser potential contributions of Fresno River water originating from Hensley Lake. These waters have been conveyed through the MID system and used for irrigation throughout the district for over 50 years. Friant water is recognized as high quality and generally of higher quality than the underlying groundwater.

MID's daily, ongoing operations currently include surveillance of conveyance facilities to ensure that accidental spills of hazardous materials that may occur near its facilities are discovered and addressed to prevent contamination of MID's water. This surveillance would continue and extend to the facilities constructed as part of this Alternative.

In addition to these precautions, MID believes it is important to monitor water quality. Water banked at Madera Ranch must not impair any designated beneficial uses of water or violate the water quality standards and objectives as defined in the Water Quality Control Plan for the Sacramento and San Joaquin River (Central Valley Regional Water Quality Control Board 2007). Therefore, in addition to its ongoing surveillance program, the MOCP water quality monitoring includes:

- sampling and analysis of recovered water leaving Madera Ranch and groundwater flowing away from Madera Ranch for total dissolved solids (TDS) to ensure that levels remain appropriate for irrigation purposes; and
- sampling and analysis of samples from drinking water wells within one mile of the Alternative for fecal coliform, TDS, and select components of TDS as specified by the MROC.

Water Accounting MID already extensively monitors flow throughout its system and those data would be used by this Alternative. Flows would be monitored where water enters Madera Ranch and where water leaves Madera Ranch. In addition, MID would monitor flows to specific recharge areas and from individual recovery wells for operational purposes. Recharge areas include swales, recharge basins, and in-lieu recharge areas.

Precipitation, wind, evaporation, and temperature would be monitored to calculate net precipitation and evaporation effects. Taken together, the data and estimates from all of these systems would be used to estimate evapotranspiration losses (from vegetation, crops, and recharge areas), recharge during conveyance, recharge into the facility, and recovery.

Recoverable Recharge Recharge that occurs during conveyance through the off-ranch MID system is part of normal MID operations and thus would not be considered banked because it is an existing condition that would not be changed by the Alternative. Flow into Madera Ranch and recharge areas would be monitored. Flow into recharge areas, minus estimated evaporation and evapotranspiration, would be considered banked. However, only 90% of the banked water would be considered recoverable, because 10% of the water applied would be retained in the bank to reduce overdraft rates.

Recovery Flow from recovery wells, minus recharge during conveyance to the perimeter of Madera Ranch, would be considered recovered water. Recharge of recovered water during conveyance would be considered returned to the water bank.

Almost all aquifer banking projects experience migration of recharged water away from recovery systems over time. In addition, a portion of early-season recharge water typically becomes inaccessible to recovery systems either through perching above silts/clays or through banking in sediments that drain too slowly to be of practical use to recovery systems. MID has concluded that actual aquifer losses cannot be reasonably predicted in a way that would adequately protect surrounding landowners from —over-extraction.” Therefore MID has committed to operational constraints to leave 10% of the recharged water behind to ensure that the Alternative results in a net reduction in the rate of overdraft and to prevent —over-recovery.”

Subsidence Monitoring Historically, subsidence has occurred to the west of Madera Ranch. However, ground elevation monitoring conducted by the U.S. Geological Survey (USGS) has indicated that no more than one foot of subsidence has occurred on Madera Ranch even though the area of Madera Ranch has been subjected to more than 100 years of intense groundwater pumping from above and below the Corcoran Clay. Therefore, it is unlikely that subsidence would be a factor in operations. Nonetheless, MID envisions that operations would include high accuracy GPS monitoring of multiple locations on Madera Ranch before and during operation of this Alternative. The elevations of on-site markers would be measured annually by MID and compared to distant USGS benchmarks to allow detection of any change in ground elevations. The MROC would monitor subsidence and has the authority to impose operational constraints or mitigation on the WSEP, depending on the level of impact, if any.

Water Recovery Operations

Water would be recovered using existing wells and new wells installed in the vicinity and downgradient of the recharge areas. As noted above, the MOCP would constrain recovery operations to prevent unacceptable impact on surrounding landowners. Recovered water would be pumped into collection piping, through the main pipeline, and into the enlarged Section 8 Canal.

Water would be conveyed via the Section 8 Canal into the MID distribution system through a series of lift stations. All of these deliveries would be made in lieu of normal surface water deliveries from Millerton Lake or Hensley Lake. Therefore, an equal volume of water would be made available in these respective reservoirs for delivery to other parts of the MID service areas, increasing the net supply of available water.

The recovery operations described above depend on farmer irrigation demand. As a consequence, recovery would be constrained to the irrigation season, typically running from mid-

March through mid-October. Peak irrigation demand, when 200 cfs of recovery capacity would be needed, typically occurs from May through August.

Use of the Water Bank Facilities by Other Entities

Under Alternative B, MID could use the entire annual recovery capacity (55,000 AF) of the facilities for its agricultural customers in some years. Based on MID's business plan, MID's capacity would be allocated as follows:

- 20,000 AF/year for MID overall in-district agricultural use;
- 5,000 AF/year for individual MID agricultural users;
- 10,000 AF/year for other Madera County agricultural users;
- 10,000 AF/year for all other Madera County users including industrial, commercial, and residential development; and
- 10,000 AF/year for environmental water obligations.

MID's Friant Division Long-Term contract with Reclamation does not provide for delivery of Millerton water to M&I users. However, there is a need for water storage by other Madera County water users. Other potential users would require separate environmental analysis and approvals, and would rely on their own water entitlements in using the proposed groundwater banking and recovery facilities.

If capacity is available after Madera County needs have been met, MID's banking facilities could be used by regional customers. Potential participants would be required to provide their own water for banking and would take delivery of banked water through exchange. Participant water would be gravity delivered through MID conveyances for recharge through the proposed facilities.

Potential non-MID participation could result in a wide array of agreements, water rights amendments, transfers, or changes to the operation of existing non-MID facilities. However, the specific tenants, potential agreements, and other related actions are not reasonably foreseeable. Therefore, analysis of these potential elements would be remote and speculative. As a result, the environmental analysis presented in this document has been conducted without regard to the specific entities or organizations that may desire to bank water in the proposed facility. Specifically, this environmental document does not evaluate:

- potential amendments to existing water rights, contracts, permits, or licenses that would allow prospective participants to use the facility;
- changes to operations of existing non-MID local, state, or federal facilities that could result from prospective participants seeking to use the facility; or
- individual water transfers or exchanges that could occur as a result of prospective participant use of the facility.

The types of actions would be subject to environmental analyses as separate projects. If any water rights amendments, water transfers, or changes in operation to federal, state, or non-MID local facilities would be required for use of the facility, the potential participant(s) would be the party(ies) responsible for complying with applicable environmental analyses requirements.

Mitigation

MID has developed a Madera Ranch Mitigation, Grazing, and Management Plan that describes future management issues associated with Madera Ranch related to grazing, water, species, vernal pools, and monitoring. A total of approximately 4,500 acres would need to be set-aside for mitigation with this alternative. Figure 2-7 MID's conceptual mitigation areas are from the Madera Ranch Mitigation, Monitoring and Reporting Plan which is provided in Appendix C of the Final EIS.

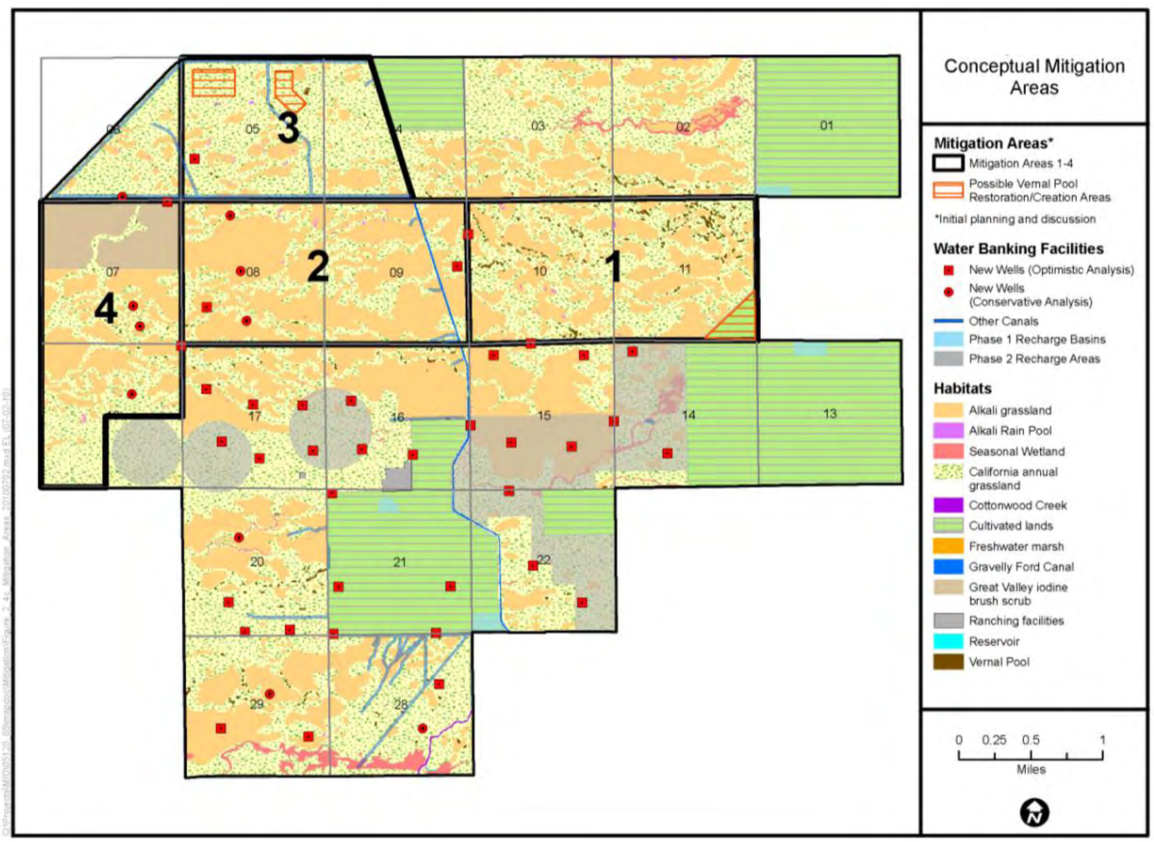


Figure 2-7 Conceptual Mitigation Areas

2.4 Reduced Alternative B – Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-owned Facilities (Proposed Action)

As described in the introduction, Reduced Alternative B is now the Proposed Action and was developed with additional agency input. Reduced Alternative B represents a scaled-back version of Alternative B that uses fewer swales to minimize effects to vernal pools and limits the number of recharge basins to the minimum for the project to be practicable. Reduced Alternative B also directs recharge activities in the swales on a priority basis to help avoid effects to vernal pools. As with Alternative B it would complete the water bank in two phases. Phase 1 would involve constructing necessary delivery infrastructure improvements (except for the Section 8 canal southwest extension), using select natural swales for recharge (550 acres versus 700 acres as proposed under Alternative B), and installing approximately five soil berms to direct recharge flows. Phase 2 would involve constructing a limited number of recharge basins (323 acres versus up to 1,000 acres under Alternative B) and facilities for recovery of banked water. Reclamation would approve banking of CVP water outside the MID service area and alteration of Reclamation-owned facilities. Similar to Alternative B, Reduced Alternative B may include funding by Reclamation, under the Omnibus Public Land Management Act of 2009, the Policy and Program Services, Challenge Grant Program: Recovery Act of 2009 Water Marketing and Efficiency Grants, or any other funding source. Regardless of whether this funding is acquired, the project components and associated effects would be the same. A description of the Reduced Alternative B, the Proposed Action, follows.

2.4.1 Phase 1 Facilities

MID would implement Phase 1 to increase the capacity of existing MID conveyance facilities to deliver water to Madera Ranch facilities. Phase 1 would use primarily natural swales as recharge areas.

Phase 1 activities would involve:

- reconditioning and extension of canals to provide at least 200 cfs of conveyance capacity into Madera Ranch;
- construction of approximately 55 acres of recharge basins on current agricultural land to regulate flow, remove sediment, and provide some recharge;
- application of recharge flows to approximately 550 acres of swales; and
- integration of approximately 2,600 acres of Madera Ranch row crops and vineyards into an in-lieu recharge program in which surface water periodically would be served in lieu of groundwater pumping subject to approval by the MROC.

Diversion and Conveyance Facilities

Upgrades to Existing Canals Figure 2-2 depicts the locations of existing canals in the vicinity of Madera Ranch. During Phase 1, MID would upgrade canals to enable gravity delivery of at least 200 cfs into Madera Ranch. Upstream portions of Cottonwood Creek, the 24.2 Canal and the Main No. 1 Canal collectively provide more than 200 cfs of gravity feed conveyance capacity above MID’s normal service needs during nonpeak irrigation months, and lesser amounts of capacity during peak irrigation months. However, the portions of these conveyances and the Section 8 Canal within two miles of the ranch are undersized, causing a bottleneck such that the capacity to deliver water to the ranch is less than 100 cfs. Specifically, the confluence of Cottonwood Creek, the Main No. 1 Canal, and the Section 8 Canal, approximately two miles east of the ranch, has a capacity of less than 100 cfs. In addition, the Section 8 Canal running from this confluence into the ranch has a capacity of less than 50 cfs, and the 24.2 Canal, 1.5 miles from the ranch, also has a capacity of less than 50 cfs and does not tie into the Section 8 Canal. The following sections summarize how these and other conveyances would be upgraded to provide up to 200 cfs delivery capacity to and from Madera Ranch.

Reclamation Conveyance Facilities

24.2 Canal Improvements MID would extend the earthen 24.2 Canal approximately 0.75 mile south to connect with the Section 8 Canal (Figure 2-8). The connector would be a buried pipeline, not an open canal. In addition, approximately 1.75 miles of the southern portion of the existing 24.2 Canal would be widened and deepened to accommodate 100 cfs of flow. In total, the extension pipeline and canal enlargement would involve moving approximately 36,000 cy of soil.

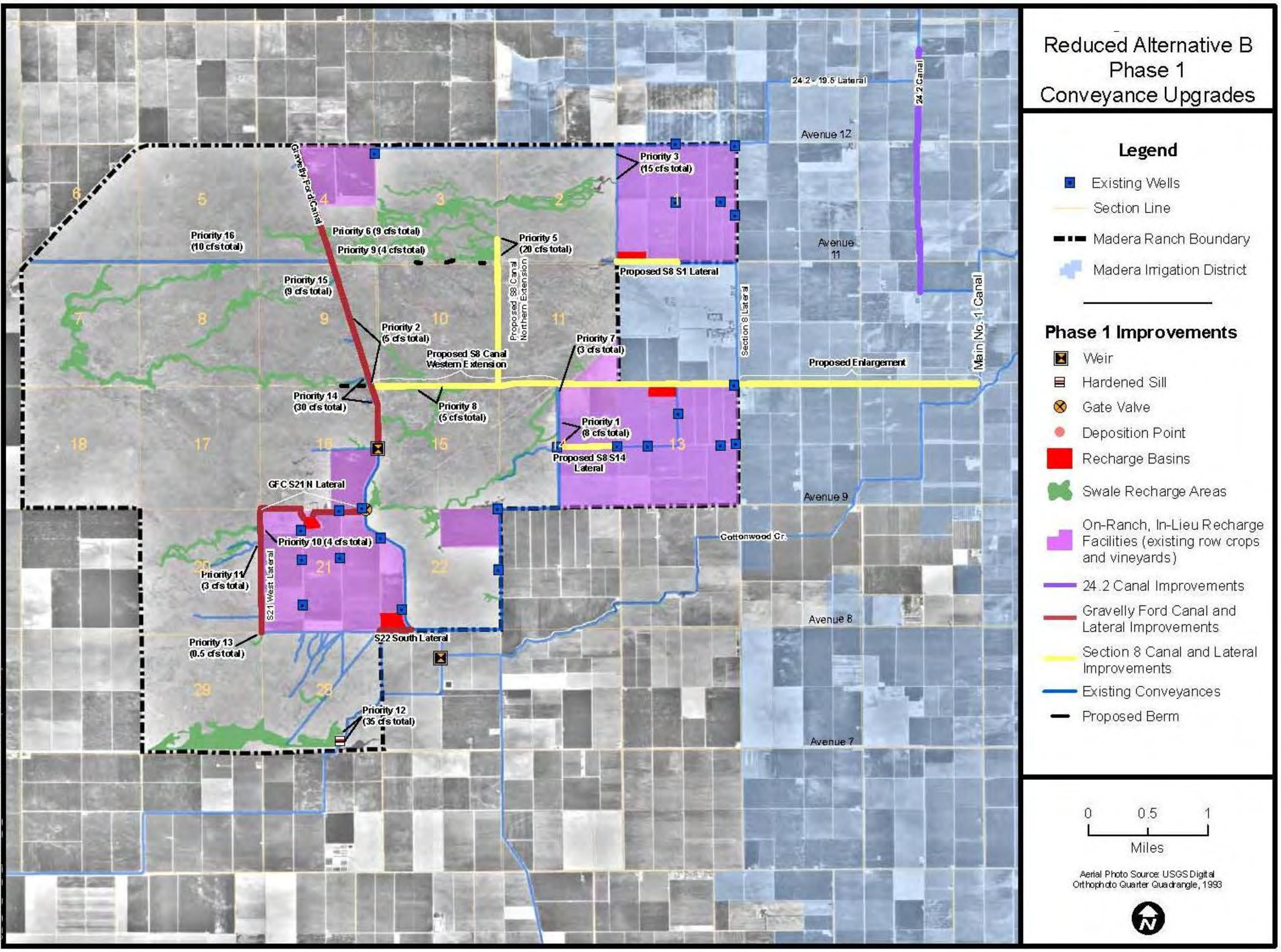


Figure 2-8 Reduced Alternative B Phase 1 Conveyance Upgrades

MID Conveyance Facilities

Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection Upgrade The existing connection between the Section 8 Canal (an earthen ditch built in the late 19th century), Cottonwood Creek, and Main No. 1 Canal would be widened and deepened to accommodate 100 cfs of flow (Figure 2-2 and Figure 2-8). Only the connection would be widened; Cottonwood Creek would not be widened as its capacity is sufficient to meet the needs of the alternative. Work would be performed in an approximately 500-foot-long and 100-foot-wide area, requiring a temporary construction easement of 1.2 acres from neighboring landowners. No new permanent easements would be required.

Section 8 Canal Upgrade An approximately 1.75-mile segment of the earthen Section 8 Canal (from Road 23 to within approximately 0.25 mile of the Madera Ranch boundary at Road 21) would be reconstructed to expand from one-way, 50-cfs capacity to two-way (flat bottomed), 200-cfs capacity (Figure 2-8). The 1.75-mile segment of the canal from 0.25 mile east of the ranch, along the north side of Section 13 and to the western edge of ranch row crop land on the north side of Section 14, would be replaced with an approximately 1.75-mile-long, 84-inch RCP, 200-cfs (two-way) pipeline placed within the channel of the existing canal.

During construction, Avenue 10 would be temporarily closed (local traffic only) to allow work on the canal. To expand the canal, an additional 40-foot corridor would be required, for a total of 8.9 acres of easement or fee simple ownership. The last 0.25 mile of the west end of the canal off-ranch would be carried in concrete pipe buried in the existing canal such that additional right-of-way would not be needed. A 40-foot-wide temporary construction easement may be required for this last 0.25 mile off-ranch (resulting in an easement of 1.2 acres). In total, this reconstruction involves moving approximately 76,000 cy of soil.

Section 8 Canal Western Extension A new, approximately 1.55-mile-long, 50- to 60-cfs earthen ditch would be constructed within a paved road in Sections 14 and 15 from the new Section 8 Canal pipeline to the GF Canal. The ditch would be constructed within the existing leveled shoulder (Figure 2-8). In total, this construction involves moving approximately 18,000 cy of soil.

Section 8 Canal Northern Extension Sections 10 and 11 are divided by a 20- to 40-foot-wide dirt farm road bordered by the remnants of a ditch. A new approximately 1.2-mile-long, 20- to 50-cfs earthen ditch would be constructed along the alignment of the old ditch (Figure 2-8). In total, this construction involves moving approximately 14,000 cy of soil.

Section 8 Canal Section 14 Lateral Extension An existing Section 8 Canal lateral (20 cfs) that flows across Section 13 would be extended approximately 0.5 mile across Section 14 (Figure 2-8). All work would be performed along the edge of row crop land. In total, this construction involves moving approximately 2,800 cy of soil.

Section 8 Canal Section 1 Lateral Extension An existing Section 8 Canal lateral (20 cfs) that flows east-west along the southern side of Section 1 would be extended approximately 0.5 mile to the southwestern corner of Section 1 (Figure 2-8). All work would be performed along the edge of row crop land.

Gravelly Ford Canal Sedimentation Basin and Flow Regulation Area With GFWD's permission, an approximately 3,000-foot-long segment of the GF Canal on the southeastern side of Section 16 would be equipped with a weir/control structure on the north side to allow use of the channel as a combined recharge area, sedimentation basin, and flow regulation area.

Gravelly Ford Canal Flow Control Weir at Cottonwood Creek With GFWD's permission, a new weir would be installed on the GF Canal approximately 1,000 feet south of Section 22 where the canal intersects and shares a channel with Cottonwood Creek. All work would be performed in the existing artificial channel and on adjacent farm roads.

Gravelly Ford Canal Section 21 Northern Lateral A new approximately 0.45-mile-long, 20- to 50-cfs earthen ditch would be constructed along the northern side of Section 21 from the GF Canal to a Phase 1 recharge basin located on farmland (Figure 2-8).

Gravelly Ford Canal Section 21 Western Lateral A new approximately 1-mile-long north/south canal would be constructed along the western side of Section 21 off of an existing 20- to 50-cfs earthen ditch bordering the southern side of the section. The new canal would be constructed on the shoulder of a dirt farm road bordering row crop land in Section 21 (Figure 2-8).

Gravelly Ford Canal Section 22 Southern Lateral A new approximately 0.28-mile-long, 20- to 50-cfs earthen ditch would be constructed along the southern side of Section 22 from the GF Canal to an existing ditch (Figure 2-8).

Cottonwood Creek Overflow Improvements A hardened sill (compacted or armored material with low potential for erosion) would be constructed on the existing Cottonwood Creek berm to protect the berm and to accommodate flow measurements. Sections 28 and 29 are inundated by Cottonwood Creek uncontrolled flows regularly during wet springs. These uncontrolled flows generally are prevented from flowing onto Avenue 7 by an earthen berm that runs along the southern boundary of Section 28 and north along the western boundary of Section 29 (Figure 2-8).

Reconditioning of Existing Canals and Ditches Reconditioning would involve reconditioning GF Canal (described below), replacement of turnout gates (described below), brush removal, repair of berms that have been worn down over time, reconstruction of segments that have been filled by recent farm operations, and installation of farm road crossings as required.

Gravelly Ford Canal Gravelly Ford Canal is an earth-lined flat-bottom channel that conveys irrigation water from the San Joaquin River to Madera Ranch. Project elements affecting Gravelly Ford Canal include:

- Construction of a new weir structure and lift station (GF Canal sedimentation basin and flow regulation area as described above);
- Grading approximately 2.6 miles of the canal back to original design contour and capacity;

- Installing approximately three to five new turnouts;
- Replacing approximately two to three old turnouts; and
- Installing one flow monitoring station.

Gravelly Ford Canal Reconditioning GF Canal would be reconditioned north of the new weir and lift station to Avenue 12 (2.6 miles). Material that has eroded from the banks and settled in the bottom of the canal would be used to reform the banks of the canal. A grader and scraper would be used in the canal bottom to recontour the canal. Approximately 16,000 cy of dirt would be moved to reshape the existing berms of the canal.

Gravelly Ford Turnouts Approximately two new east berm turnouts would be installed to deliver water into the recharge areas. Three west berm turnouts would be replaced and three new west berm turnouts would be constructed (one to a recharge basin in agricultural lands, one gate structure to a new lateral canal system constructed in uplands, and one to upland recharge areas). A flow monitoring station would also be installed. Each turnout is approximately 3-feet wide by 6-feet long by 6-feet tall and is/will be buried in the existing banks of the canal. The turnouts are constructed off-site at MID headquarters. Construction of the turnouts would require excavating approximately 32 cy of soil and the addition of three cy of fill material to install a gate and compact the soil adjacent to it.

Recharge Facilities

Recharge Basins Phase 1 would involve construction of approximately 55 acres of basins, approximately four basins that are 1,100 feet square, as shown in Figure 2-3 on agricultural land in order to:

- help regulate flows,
- allow settling of sediments before application of water to swales, and
- provide some recharge capacity.

The preliminary locations of four Phase 1 recharge basins are entirely on current agricultural land in Sections 1, 13, 21, and 22. The basins would be designed with 1.5:1 to 2:1 interior side slopes and average depths of four to five feet and surrounded by low earthen dikes created from the dirt excavated from the basin. Construction of the Phase 1 recharge basins could involve the movement of approximately 444,000 cy of soil.

Swale Recharge Areas The Proposed Action would entail diversion of water into approximately 550 acres of swales. The water would be conveyed to Madera Ranch through the existing and upgraded MID conveyances and to the swales through the existing, rehabilitated, and new ditches described above. At the head of each swale, a manually operated farm turnout (equipped with a gate valve and totalizing flow meter) would be installed to regulate and measure the flow into each swale. Several turnouts currently exist on GF Canal and these would be replaced and several new ones will be added. Flows at each turnout, based on pilot studies, would be no greater than 20 cfs and would average five cfs at the turnout. Maximum overall flows would be around one cfs per acre of application. Locations of the swales anticipated to be used during Phase 1 are depicted on Figure 2-3.

In-Lieu Recharge Facilities Madera Ranch includes 2,666 acres of row crops and vineyards that are irrigated entirely by a system of 23 wells. MID would recondition existing turnouts and install new turnouts from the Proposed Action canals, pipelines, and ditches to enable delivery of surface water to these fields in lieu of groundwater pumping (Madera Irrigation District 2008).

These agricultural fields were purchased from MID in July 2008 by Grimmway Enterprises, Inc. Grimmway will continue to manage the property for agricultural uses. However, MID has retained rights to existing and future easements that would allow the Proposed Action to be implemented.

2.4.2 Phase 2 Facilities

Phase 2 would expand the areas used to recharge, develop wells and piping to recover the banked water, and install pumps to deliver the recovered water (Figures 2-9 to 2-11).

Phase 2 activities for recharge and recovery facilities would involve:

- additional upgrades to existing canals,
- construction of up to 323 acres of new on-site recharge basins and canals as required to supplement Phase 1 facilities and achieve 200 cfs of recharge capacity (if required),
- use of up to 15 existing wells for recovery,
- installation of up to 49 new wells and recovery pipelines (in phases over several years) to provide 200 cfs of recovery capacity, and
- installation of up to 12 lift stations on MID canals and one lift station on GF Canal (in phases over several years) to provide 200 cfs of pump-back capacity into the MID service area.

Diversion and Conveyance Facilities

Recovery Pipeline An approximately 1.75-mile-long, 72-inch to 84-inch RCP, 135- to 200-cfs (two-way) buried pipeline would be installed under the road that runs diagonally across Sections 14 and 15. The pipeline would extend from the Phase 1 Section 8 Canal upgrade (200-cfs pipeline) to the GF Canal beneath an existing 30- to 40-foot-wide dirt farm road (Figure 2-4).

Gravelly Ford Canal Section 21 Northern Lateral The 0.45-mile-long Phase 1 ditch along the northern side of Section 21 would be replaced with an approximately 2.1-mile-long, 135-cfs, east-west earthen lateral canal along the north side of Sections 21 and 20 with two north-south sub-lateral canals running northward along the east and the west sides of Section 17.

Depending on the recharge basin acreage and construction methods, up to 3.2 miles of 20- to 100-cfs earthen ditches would be constructed within the Phase 2 recharge basin area to distribute water into recharge areas.

Recharge Facilities

Recharge Basins Depending on the performance of Phase 1 recharge facilities, up to 323 acres of recharge basins may be constructed within a 1,300-acre area (Figures 2-10 and 2-11).

Following surveys as outlined in the Environmental Commitments section, MID would begin construction of the basins. The following steps to construct recharge basins may occur.

- *Stage 1:* Berming of recharge area boundaries along topographic contours using farm roads wherever possible and farm grading techniques, but no excavation (similar to unleveled rice fields).
- *Stage 2:* Deep ripping of corridors within the bermed areas, interspersed with corridors of undisturbed land.
- *Stage 3:* Excavation of basins varying from four to five feet deep.

The final number of recharge basins constructed and techniques summarized above is uncertain, and the highest estimated acreage is highly unlikely to be required. This EIS evaluates the potential effects associated with up to 323 acres of excavated basins. Recharge basins would be arranged to minimize species and habitat effects, and a site visit in July 2010 with the resource agencies indicated MID should proceed with basin construction first on the west side of GF Canal (Figure 2-10); MID would maximize the use of this area before constructing basins on the eastern side of the property.

Construction of the recharge basins and internal routing ditches could involve the moving of up to 2.5 million cy of soil. Basins would be designed with 3:1 interior side slopes and average depths of four to five feet. Low earthen dikes would be constructed around the recharge basins using excavated materials. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation.

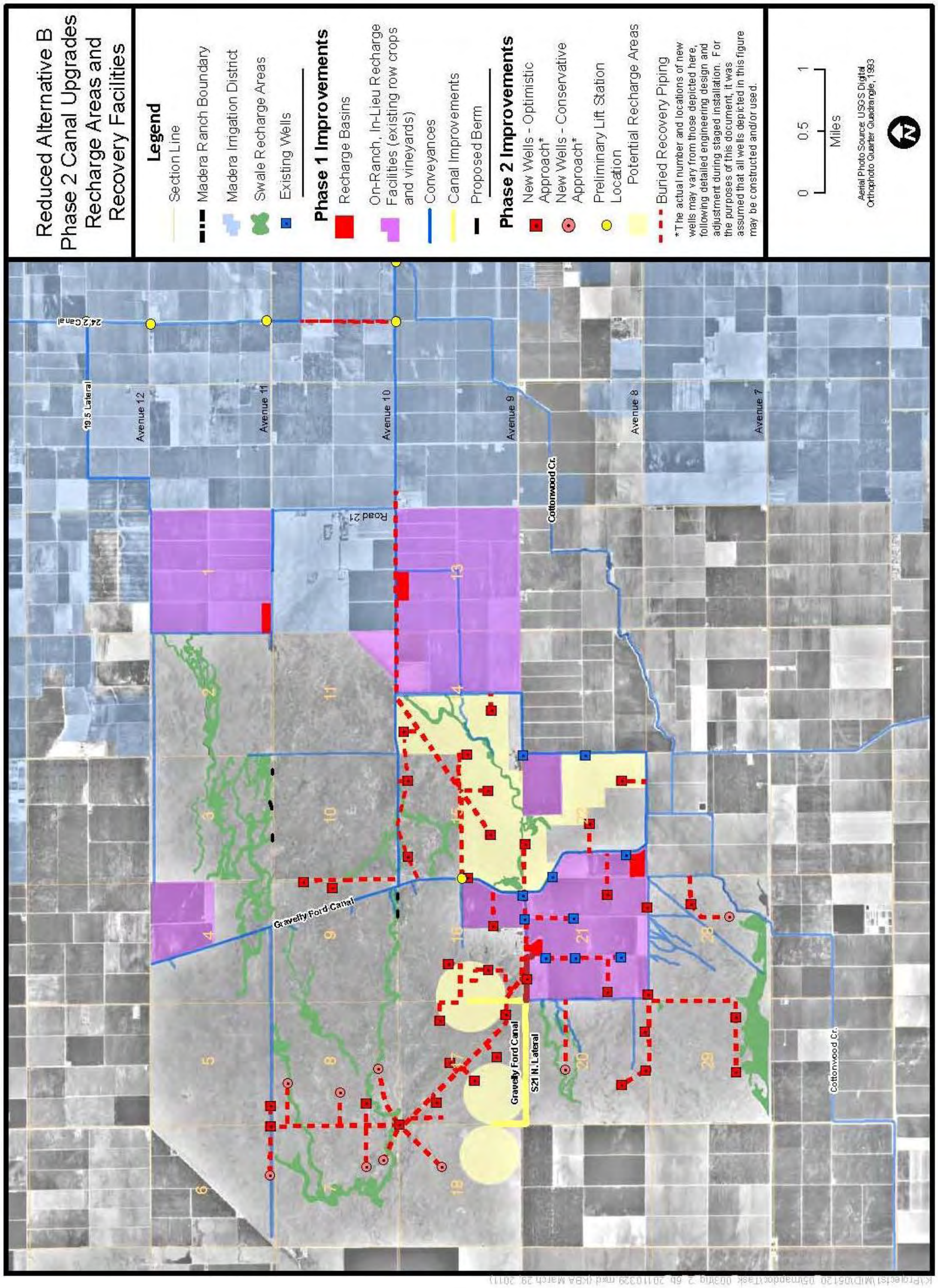


Figure 2-9 Reduced Alternative B Phase 2 Canal Upgrades, Recharge Areas, and Recovery Facilities

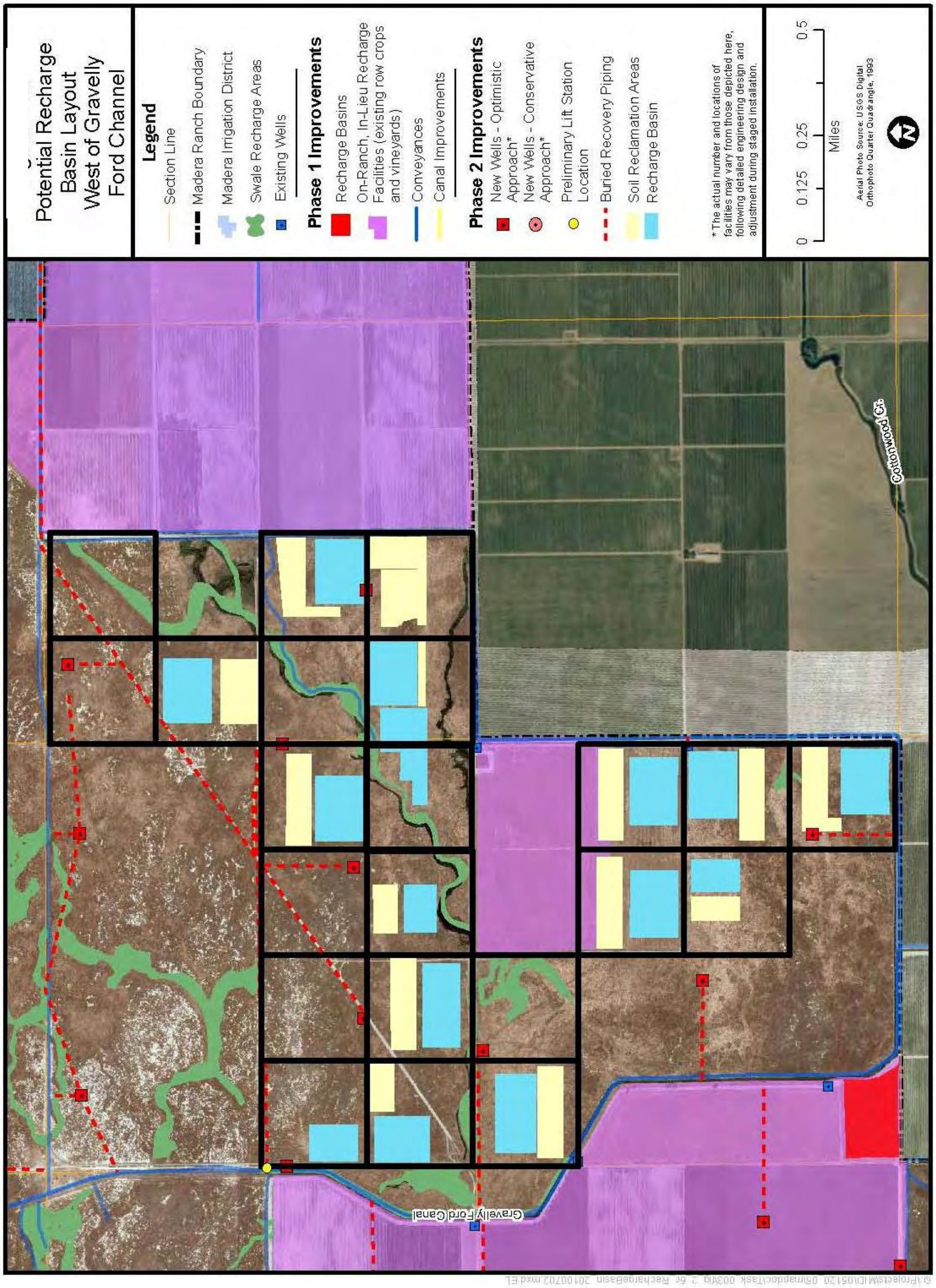


Figure 2-10 Potential Recharge Basin Layout West of Gravelly Ford Canal

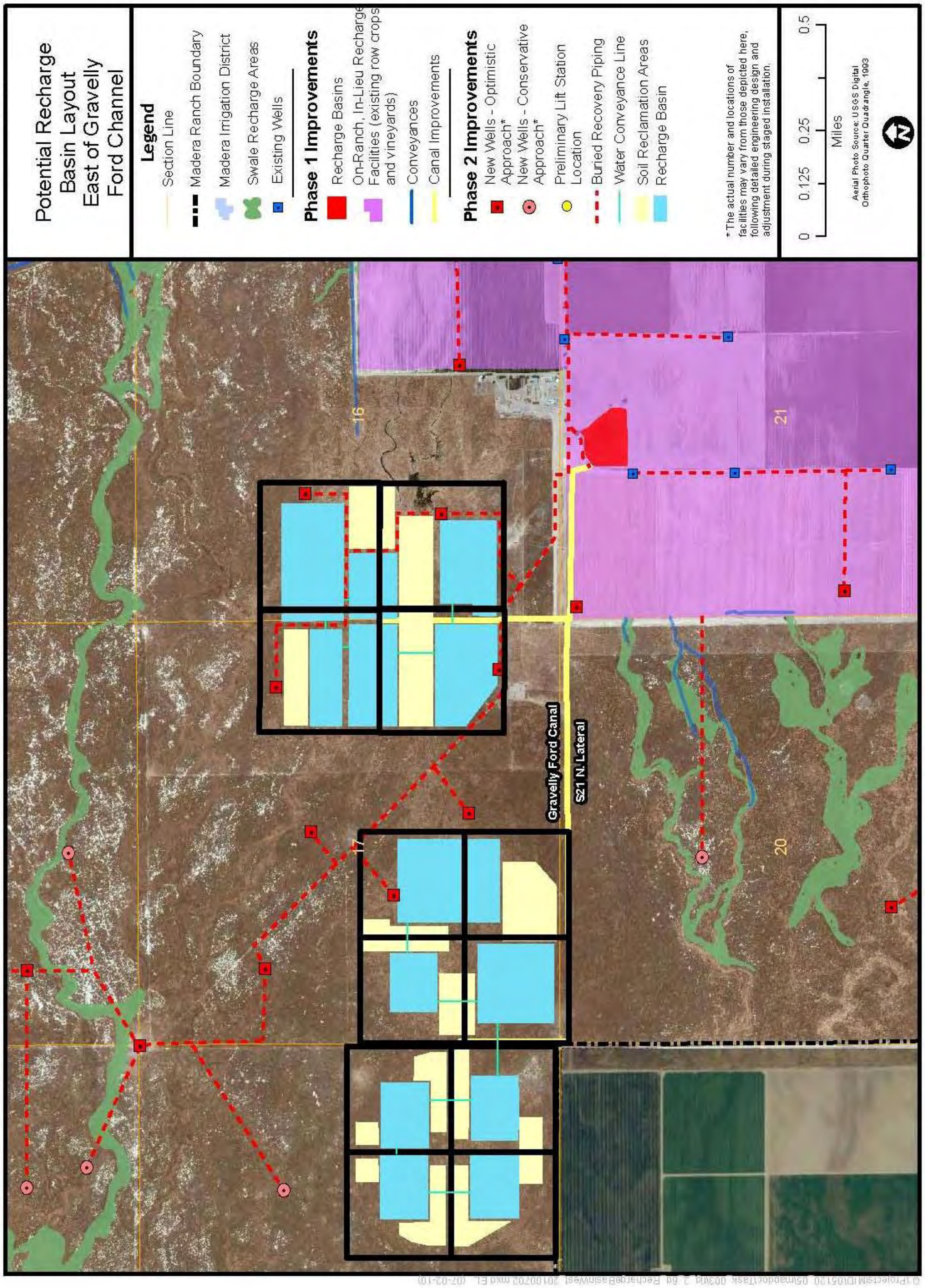


Figure 2-11 Potential Recharge Basin Layout East of Gravelly Ford Canal

Recovery Facilities

These elements are the same as described under Alternative B.

2.4.3 Construction

Conveyance Facilities

These elements are the same as described under Alternative B.

Recharge Facilities

Phase 1 recharge swales would largely remain unaltered and would not be subject to any construction activities. However, to ensure water is directed to desired swale areas up to five micro-berms could be installed. The location of these are illustrated in Figure 2-9. They could be approximately 100 feet long and a maximum of three feet high at the center to provide sufficient freeboard and long-term stability. MID and farmers on Madera Ranch routinely perform this type of earthwork. This project element would be completed in one day using district-owned equipment as follows:

- MID would perform a topographic survey along the fence line to confirm required dimensions;
- MID would temporarily remove fencing as necessary;
- MID would use a front-end loader to haul in the dirt from on-site canal excavation areas, place it, and compact it in approximately 6-inch lifts by driving over the fill material with the rubber tires of the loader; and
- following emplacement and compaction, MID would re-install the fence.

Construction of Recharge Basins (Phase 2) The staging of recharge basin construction proposed would proceed as follows.

- *Stage 1:* Berming of recharge area boundaries along topographic contours and using farm roads wherever possible. These recharge areas would be constructed using graders that follow prestaked topographic contours to raise 1- to 3-foot-high berms around the downslope portions of areas ranging from five acres to 80 acres. Berm material would be obtained from an approximate 50-foot-wide corridor parallel to the interior toe of the berm. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation.
- *Stage 2:* Deep ripping of corridors within the bermed areas, interspersed with corridors of undisturbed land. This will be done to ensure deeper percolation is maximized during project operation.
- *Stage 3:* Excavation of basins varying from four to five feet deep. Because of the demonstrated permeability of soils at Madera Ranch, Stage 3 recharge basins are unlikely to be required. However, in the event these basins were used, they would be constructed to minimize species and habitat effects, and possibly clustered in sets of two to four varying in size from five acres to 80 acres, with the first basin in each set serving as both a settling and a recharge basin. Basins would be designed with 1.5:1 to 2:1 interior side slopes and average depths of four to five feet. After excavation, each basin would be shallow-ripped or disked by construction equipment in order to break up compaction of the bottom soils in the recharge basin. Low earthen dikes would be constructed around

the recharge basins using excavated materials. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation. Excess soil removed during excavation would be managed to ensure that top layers are stockpiled, excavated soils would be mounded between basins, and stockpiled topsoil would be placed on top of the soil pile.

It is estimated that Stage 3 recharge basins would be constructed using:

- three to 20 heavy diesel-powered scrapers (40- to 60-yard capacity);
- three to five 500- hp diesel-powered skip loaders;
- 15 to 30 heavy-duty, off-road-type trucks (60-yard capacity);
- three to five large, diesel-powered, crawler-type tractors; and
- three to five diesel-powered motor graders.

The final combination of the acreages and techniques summarized above is uncertain. However, as previously discussed, this EIS evaluates the potential effects associated with up to 323 acres of excavated basins.

Recovery Facilities

These elements are the same as described under Alternative B.

Staging Areas

These elements are the same as described under Alternative B.

2.4.4 Maintenance

These elements are the same as described under Alternative B.

2.4.5 Operations

These elements are the same as described under Alternative B.

Mitigation

MID has developed a Madera Ranch Mitigation, Grazing, and Management Plan that describes future management issues associated with Madera Ranch related to grazing, water, species, vernal pools, and monitoring of conservation lands.

MID has proposed mitigation for the potential effects to protected species and their habitats that could result from implementation of the Proposed Action. Three mitigation areas are proposed, the first two areas would include 2,357 acres of land managed to provide affected species habitat. The third mitigation area includes 3,456 acres, approximately 375 acres of which are planned as recharge swales.

These lands would be managed for both recharge and species protection purposes, and would provide relatively natural lands between the swales that can provide habitat for the effected species and connects the compensation areas (Figure 2-12).

Vernal pools created or restored would be inoculated with cysts and seeds from other high quality vernal pools on site in accordance with USFWS-approved methods.

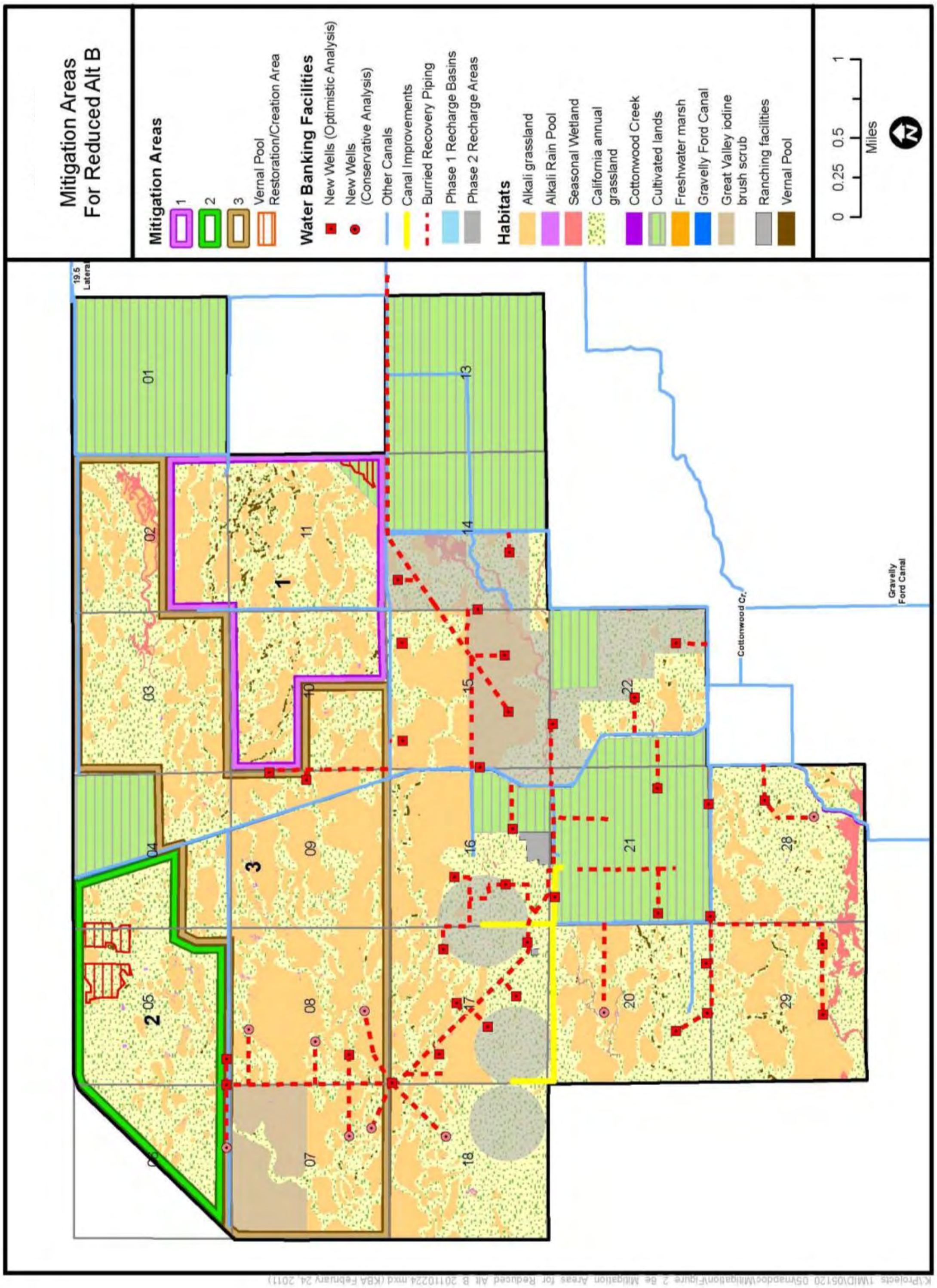


Figure 2-12 Mitigation Areas for Reduced Alternative B

2.5 Alternative C – Water Banking Outside the MID Service Area without Swales, and Alteration of Reclamation-owned Facilities

Alternative C is a variation of Alternative B that would complete the water bank in two phases and replace natural swale recharge solely with recharge basins. Phase 1 would involve recharge-related facilities only. Phase 2 would involve facilities for recovery of banked water. Reclamation would approve banking of CVP water outside the MID service area and alteration of Reclamation-owned facilities. Similar to Alternative B, Alternative C includes funding by Reclamation, under the Omnibus Public Land Management Act of 2009, the Policy and Program Services, Challenge Grant Program: Recovery Act of 2009 Water Marketing and Efficiency Grants, or any other funding source. Regardless of whether this funding is acquired, the project components and associated effects would be the same. A description of Alternative C follows.

2.5.1 Phase 1 Facilities

MID would implement Phase 1 to increase the capacity of existing MID conveyances to deliver water to Madera Ranch facilities. Phase 1 would use engineered basins as recharge areas (Figure 2-13).

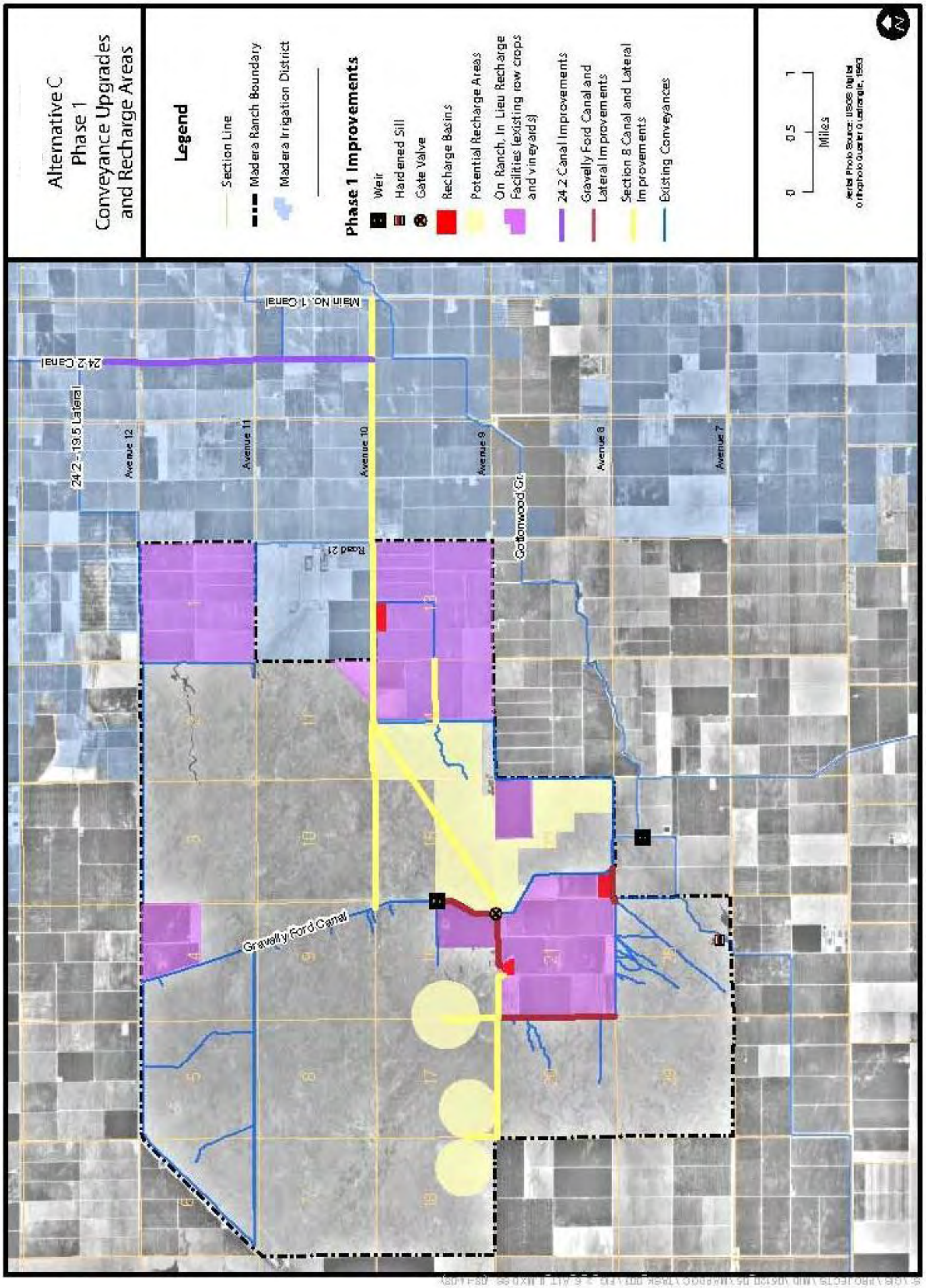


Figure 2-13 Alternative C Phase 1 Conveyance Upgrades and Recharge Areas

Phase 1 activities would involve:

- reconditioning and extension of existing canals to provide at least 200 cfs of conveyance capacity into Madera Ranch;
- construction of up to 1,000 acres of new on-site recharge basins and canals as required to achieve 200 cfs of recharge capacity; and
- integration of approximately 2,600 acres of Madera Ranch row crops and vineyards into an in-lieu recharge program in which surface water periodically would be served in lieu of groundwater pumping subject to approval by the MROC.

Diversion and Conveyance Facilities

Under Alternative C, conveyance facilities would be identical to those proposed under Alternative B, with the exception that neither the Section 8 Canal Northern Extension nor the Section 8 Canal Section 1 Lateral Extension would be required and Phase 2 conveyance upgrades under Alternative B would be constructed during Phase 1 of Alternative C to convey water to the engineered recharge basins.

Recharge Facilities

Recharge Basins Approximately 1,000 acres of recharge basins would be constructed within a 1,300-acre area. Recharge basins would be clustered in sets of three or four, varying in size from five to 80 acres, with the first basin constructed in each set serving as both a settling and a recharge basin.

Construction of the recharge basins and internal routing ditches could involve the movement of up to approximately 7.7 million cy of soil. Basins would be designed with 1.5:1 to 2:1 interior side slopes and average depths of four to five feet. Low earthen dikes would be constructed around the recharge basins using excavated materials. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation.

In-Lieu Recharge Facilities As under Alternative B, MID would recondition existing turnouts and install new turnouts as in the Alternative B canals, pipelines, and ditches to enable delivery of surface water to these fields in lieu of groundwater pumping.

2.5.2 Phase 2 Facilities

Phase 2 would develop wells and piping to recover the banked water, and install pumps to deliver the recovered water as shown in Figure 2-14.

Phase 2 recharge and recovery facilities would involve:

- up to 15 existing wells for recovery;
- up to 49 new wells and recovery pipelines (in phases over several years) to provide 200 cfs of recovery capacity; and

- up to 12 lift stations on MID canals and one lift station on GF Canal (in phases over several years, total of 13 lift stations) to provide 200 cfs of pump-back capacity into the MID service area.

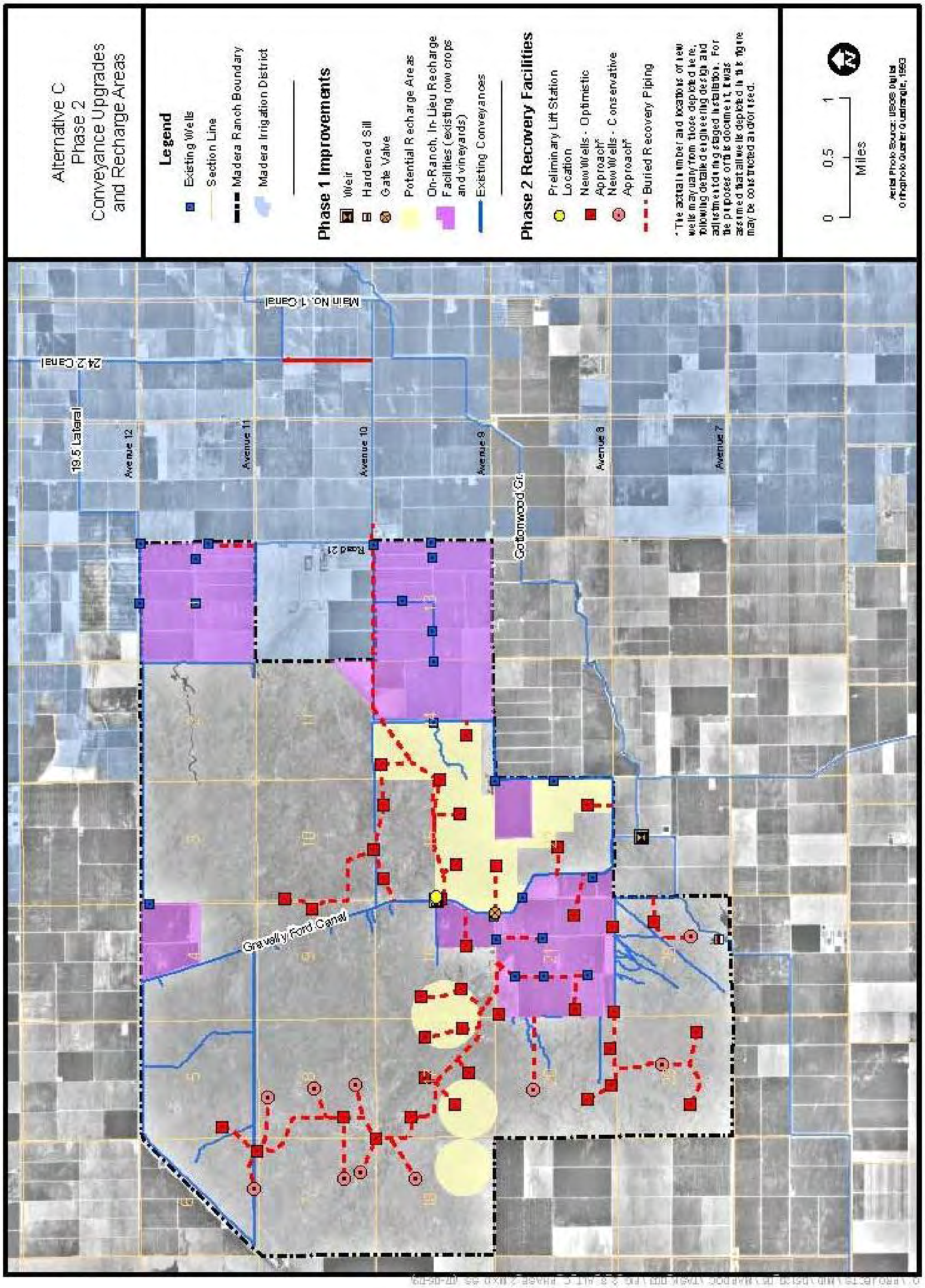


Figure 2-14 Alternative C Phase 2 Conveyance Upgrades and Recharge Areas

Recovery Facilities

Recovery Wells As under Alternative B, banked water would be recovered using up to 15 existing wells and approximately 49 new wells (Figure 2-14).

Recovery Pipelines and Electrical Facilities As under Alternative B, up to 11.6 miles of 8-inch- to 60-inch-diameter PVC to RCP buried recovery pipelines would run from recovery wells to the GF Canal and the Section 8 Canal for delivery back to farmers (Figure 2-14).

2.5.3 Construction

All construction methodologies necessary to construct Alternative C are described in detail under Alternative B – Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities.

Recovery Lift Stations

As under Alternative B, up to 13 lift stations would be required on the same conveyances used to deliver water into the water bank (Figure 2-14).

2.5.4 Maintenance

All maintenance methodologies necessary to operate Alternative C are described in detail under Alternative B – Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities.

Maintenance Corridors

As under Alternative B, the maintenance corridors would include new roads in the recharge basin area and areas with heavy disturbance, and unimproved routes in grassland areas.

2.5.5 Operations

Please refer to the Operations subsection of Alternative B – Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities. Discussion related to swales would not apply to Alternative C, but all other aspects of recharge operations would be identical.

Mitigation

Mitigation anticipated for Alternative C could be approximately 3,500 acres based on effects from facility and recharge basin construction.

2.6 Alternative D – Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Under Alternative D, MID would enter into an agreement with GFWD to improve the GF Canal to allow water to be conveyed from the San Joaquin River through the GF Canal to Madera Ranch for banking of water and recovery of water from the ranch back through the canal to the river. The existing GFWD river pumping plant would be upsized; the existing, associated pipeline replaced with a larger-diameter line; the GF Canal regraded to a flat-bottom (zero slope) configuration to allow two-way flow; a new connection to the river constructed to allow recovery water to reach the river without flowing through the pumps; and appropriate gate structures constructed. On-site improvements allowing water banking and extraction, including a pumping plant and pipeline to allow distribution of water uphill from the GF Canal, would be constructed.

MID would complete Alternative D in two phases. Phase 1 would involve recharge-related facilities only. Phase 2 would involve supplemental recharge facilities and facilities for recovery of banked water. Reclamation would approve the banking of CVP water outside the MID service area as described under Alternative B. No alteration of Reclamation-owned facilities would occur under Alternative D. However, similar to Alternative B, Alternative D includes funding by Reclamation, under the Omnibus Public Land Management Act of 2009, the Policy and Program Services, Challenge Grant Program: Recovery Act of 2009 Water Marketing and Efficiency Grants, or any other funding source. Regardless of whether this funding is acquired, the project components and associated effects would be the same.

2.6.1 Phase 1 Facilities

MID would implement Phase 1 to increase the capacity of existing conveyances to deliver water to Madera Ranch.

Phase 1 would use primarily natural swales as recharge areas. Phase 1 activities would involve:

- reconditioning of existing canals to provide at least 200 cfs of conveyance capacity into Madera Ranch;
- construction of approximately 26 acres of recharge basins on current agricultural land to regulate flow, remove sediment, and provide some recharge;
- application by MID of recharge flows to approximately 700 acres of swales; and
- integration of approximately 2,600 acres of Madera Ranch row crops and vineyards into an in-lieu recharge program in which surface water would be periodically served in lieu of groundwater pumping subject to approval by the MROC.

Diversion and Conveyance Facilities

Upgrades to Existing Canals Figure 2-2 depicts the locations of existing canals in the vicinity of Madera Ranch. During Phase 1, MID would upgrade existing canals to enable delivery of at least 200 cfs into Madera Ranch. The following sections summarize how these and other conveyances would be upgraded to provide 200 cfs of delivery capacity to and from Madera Ranch.

Gravelly Ford Canal The configuration of the GF Canal, as shown on record drawings from 1966, indicates that the canal cannot convey 200 cfs, in part because of its highly irregular bottom. To allow a two-way flow of up to 200 cfs, the canal would have to be regraded, and the intake pipeline on the San Joaquin River connecting the pump plant to the open canal segments enlarged to a 72-inch-diameter concrete pipe. A flow meter would be installed in the pipeline. In addition to the canal improvements, an upsized pumping plant and pipeline improvements would be completed. Additional improvements would involve:

- installation of three checkdams,
- reconstruction of culvert crossings and farm road bridges, and

- installation of a Parshall flume at the edge of Madera Ranch to measure recovery volumes.

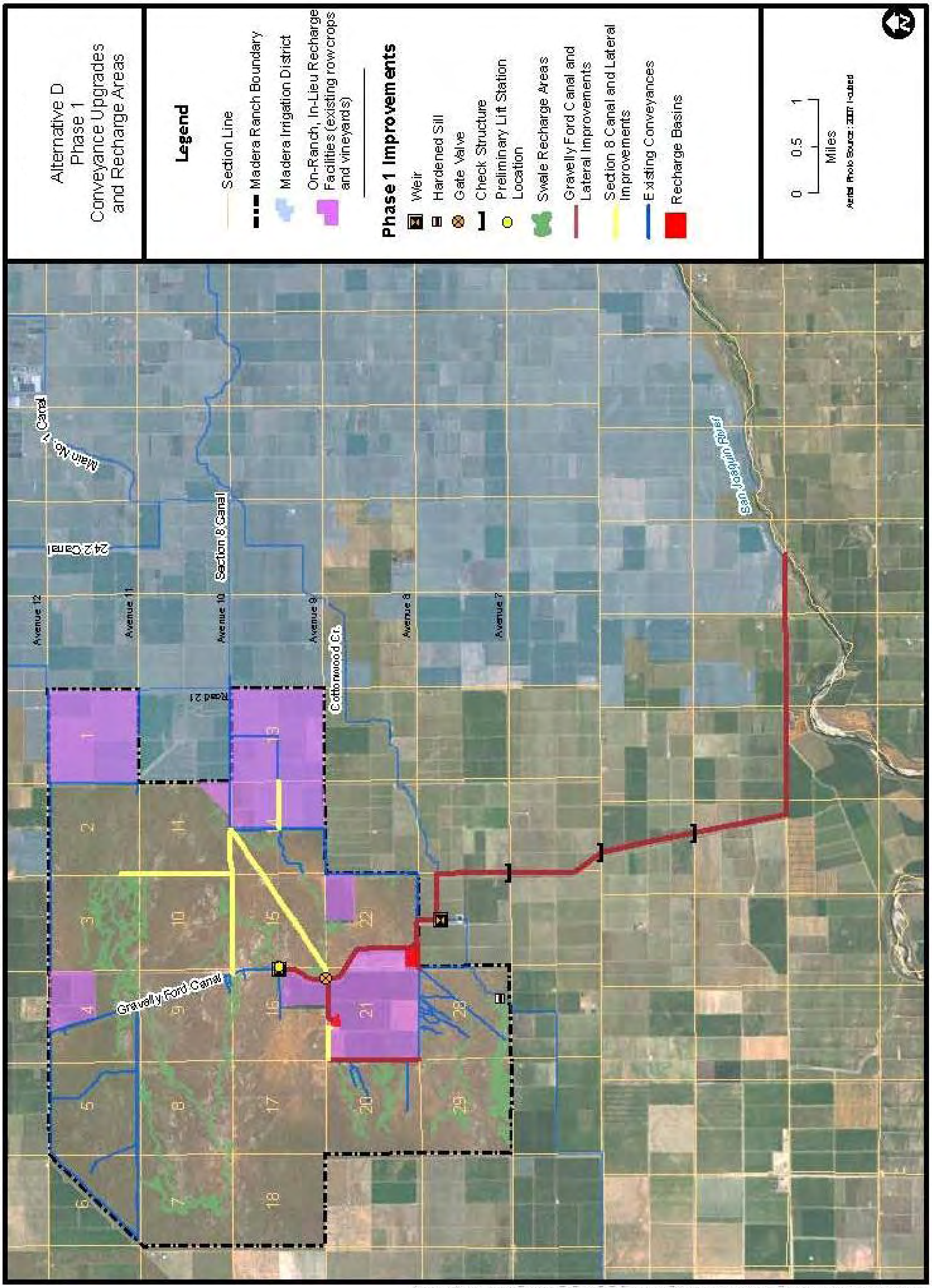


Figure 2-15 Alternative D Phase 1 Conveyance Upgrades and Recharge Areas

Additionally, a 400-hp pumping plant, consisting of two 200-hp pumps, would be required on-ranch to move water from the GF Canal uphill to the east as far as Section 13 so that water could be delivered to swales for recharge and in-lieu fields east of the canal.

Gravelly Ford Canal Sedimentation Basin and Flow Regulation Area With GFWD's permission, an approximately 0.6 mile segment of the GF Canal on the southeastern side of Section 16 would be equipped with a weir/control structure on the north side to allow use of the channel as a combined recharge area, sedimentation basin, and flow regulation area.

Gravelly Ford Canal Flow Control Weir at Cottonwood Creek As under Alternative B, with GFWD's permission, a new weir would be installed on the GF Canal approximately 1,000 feet south of Section 22 where the canal intersects and shares a channel with Cottonwood Creek (Figure 2-15).

Section 8 Canal/Gravelly Ford Canal Connection As under Alternative B, a new, approximately 1.55-mile-long, 20- to 50-cfs, earthen ditch would be constructed adjacent to a paved road in Sections 13, 14 and 15 to the GF Canal from the existing terminus of the Section 8 Canal (Figure 2-15).

Gravelly Ford Canal Section 21 Northern Lateral As under Alternative B, a new approximately 0.45-mile-long, 20- to 50-cfs earthen ditch would be constructed along the northern side of Section 21 from the GF Canal to a Phase 1 recharge basin located on farmland (Figure 2-15).

Gravelly Ford Canal Section 21 Western Lateral As under Alternative B, a new approximately one-mile-long north/south canal would be constructed along the western side of Section 21 off of an existing 20- to 50-cfs earthen ditch bordering the southern side of the section (Figure 2-15).

Gravelly Ford Canal Section 22 Southern Lateral As under Alternative B, a approximately 0.28-mile-long, 20-to 50-cfs earthen ditch would be constructed along the southern side of Section 22 from the GF Canal to an existing ditch (Figure 2-15).

Section 8 Canal Southwestern Extension Sections 14 and 15 are bisected diagonally by a 30- to 40-foot-wide, dirt farm road that was previously a ditch. As under Alternative B, a new approximately 1.8-mile-long, 20-cfs earthen ditch would be constructed from the Section 8 Canal along the shoulder of this road and to the GF Canal. This canal would require at least one pumping plant to deliver water from the GF Canal to the east (Figure 2-15).

Section 8 Canal Northern Extension As under Alternative B, Sections 10 and 11 are divided by a 20- to 40-foot-wide dirt farm road bordered by the remnants of a ditch. A new approximately 1.2-mile-long, 20- to 50-cfs earthen ditch would be constructed along the alignment of the old ditch (Figure 2-15).

Section 8 Canal Section 14 Lateral Extension An existing Section 8 Canal Lateral (20 cfs) that flows across Section 13 would be extended 0.5 mile across Section 14. All work would be performed along the edge of row crop land. This canal would require one pumping plant to deliver water to the east (Figure 2-15).

Reconditioning of Existing Ditches As under Alternative B, reconditioning would involve replacement of turnout gates, brush removal, repair of berms that have been worn down over time, reconstruction of segments that have been filled by recent farm operations, and installation of farm road crossings as required.

Recharge Facilities

Recharge Basins Phase 1 would involve construction of approximately 26 acres of basins, as shown in Figure 2-15, on agricultural land in order to:

- help regulate flows,
- allow settling of sediments prior to application of water to swales, and
- provide some recharge capacity.

The preliminary locations of two Phase 1 recharge basins are entirely on current agricultural land in Sections 21 and 22. The basins would be designed with 1.5:1 to 2:1 interior side slopes and average depths of four to five feet surrounded by low earthen dikes. Construction of the Phase 1 recharge basins could involve the movement of approximately 210,000 cy of soil. Topsoil would be segregated during excavation and respread over the berm and construction disturbance areas to promote reestablishment of vegetation.

Swale Recharge Areas As under Alternative B, water would be diverted into approximately 700 acres of swales. The water would be conveyed to Madera Ranch through the existing and upgraded MID conveyances and GF Canal and to the swales through the existing, rehabilitated, and new ditches described above. Locations of the swales anticipated to be used during Phase 1 are depicted on Figure 2-15.

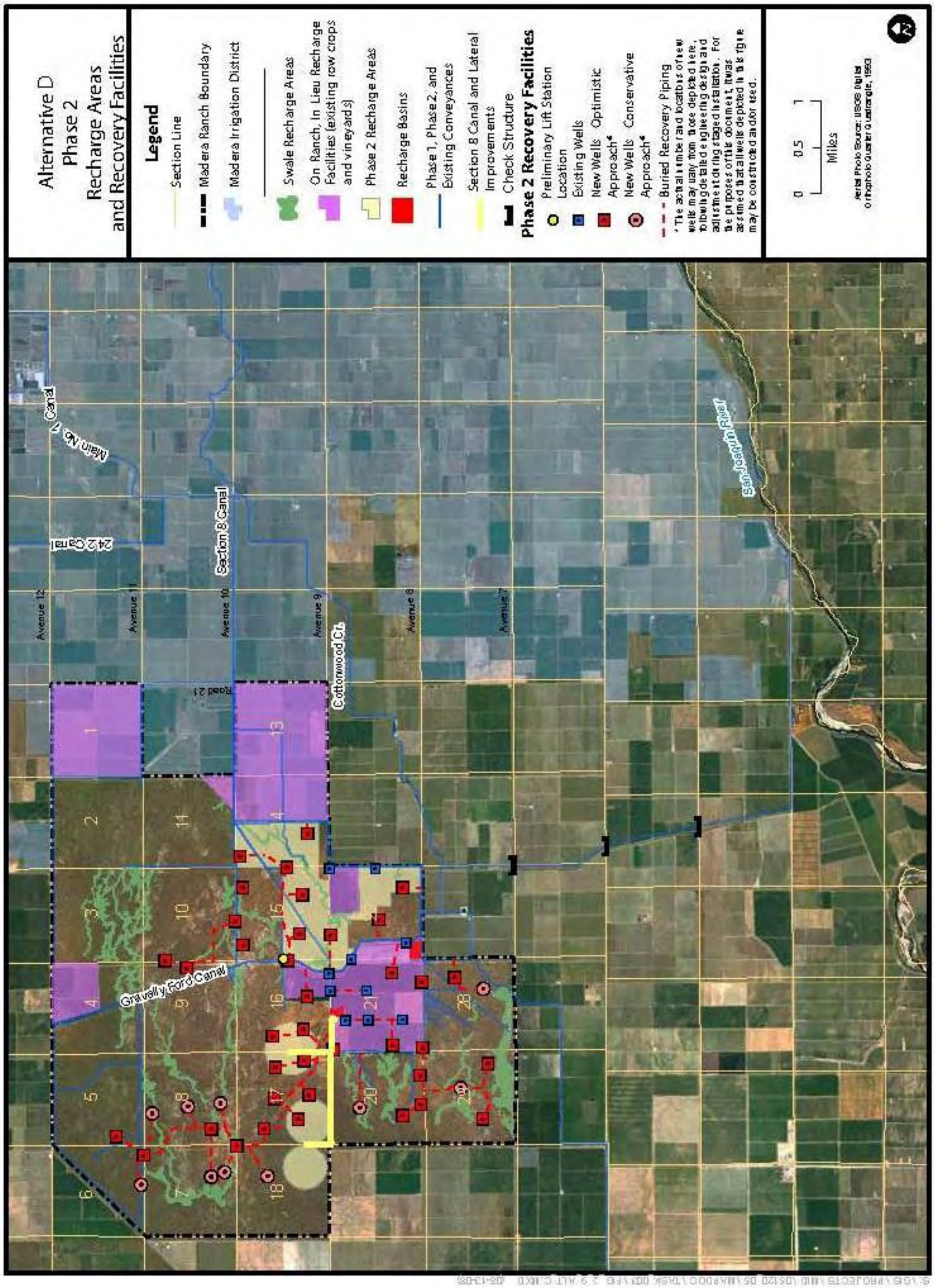
In-Lieu Recharge Facilities As under Alternative B, MID would recondition existing turnouts and install new turnouts from canals, pipelines, and ditches to enable delivery of surface water to these fields in lieu of groundwater pumping.

2.6.2 Phase 2 Facilities

Phase 2 would require the construction of wells and piping to recover the banked water, and installation of pumps to deliver the recovered water as shown in Figure 2-16.

Phase 2 recharge and recovery facilities would use or include:

- up to 15 existing wells for recovery,
- up to 49 new wells and recovery pipelines (in phases over several years) to provide 200 cfs of recovery capacity, and
- one lift station on GF Canal to provide 200 cfs of pump-back capacity to the San Joaquin River.



Aerial Photo Source: USGS Digital Orthophoto Quarter Quadrangle, 1993

Figure 2-16 Alternative D Phase 2 Recharge Areas and Recovery Facilities

Diversion and Conveyance Facilities

Upgrades to Existing Canals As under Alternative B, up to 3.2 miles of 20- to 100-cfs earthen ditches would be constructed within the Phase 2 basin window to distribute water into recharge areas.

Gravelly Ford Canal Section 21 Northern Lateral As under Alternative B, the 0.45-mile-long Phase 1 ditch along the northern side of Section 21 would be replaced with an approximately 2.1-mile-long, 135-cfs east-west earthen lateral canal along the north side of Sections 21 and 20 with two north-south sub-lateral canals running northward along the east and the west sides of Section 17.

Recharge Facilities

Recharge Basins As under Alternative B, depending on the performance of Phase 1 recharge facilities, up to approximately 1,000 acres of recharge basins may be constructed in a 1,300-acre area.

Recovery Facilities

Recovery Wells As under Alternative B, banked water would be recovered using up to 15 existing wells and approximately 49 new wells (see Figure 2-16).

Recovery Pipelines and Electrical Facilities As under Alternative B, up to 11.6 miles of 8-inch- to 60-inch-diameter PVC to RCP buried recovery pipelines would run from recovery wells to the GF Canal (Figure 2-16).

Recovery Lift Station One lift station would be constructed along the GF Canal to pump water recovered from wells back to the San Joaquin River through the canal

2.6.3 Construction

All construction methodologies necessary to construct MID facilities under Alternative D are described in detail under Alternative B – Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities. Construction of facilities on GFWD land and in GF Canal is described below.

Gravelly Ford Canal Improvements

Construction methods necessary for the upgrade of GF Canal are discussed in Alternative B under the subsections Upgrade of Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection, Weir Installation, and Construction of Recovery Lift Stations. The regrading of the off-ranch portions of GF Canal will require the movement of an additional 15,000 cy of soil.

2.6.4 Maintenance

All maintenance activities necessary to operate Alternative D are described in detail under Alternative B – Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities.

Maintenance Corridors

As under Alternative B, the maintenance corridors would include new roads in the recharge basin area and areas with heavy disturbance, and unimproved routes in grassland areas.

2.6.5 Operations

Madera Ranch operations, including banking, water recovery, and maintenance to support banking and recovery, are described below, including measures to monitor potential effects on neighboring farmers and districts (adjacent stakeholders).

Water Banking

Please refer to the Banking subsection of Alternative B – Water Banking outside MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities. Fewer swales, including those in Section 2, would be used under this alternative.

Monitoring and Operational Constraints Plan

Please refer to the Monitoring and Operational Constraints Plan subsection of Alternative B-Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities. The MROC would revise the plan to accommodate additional monitoring in GF Canal if this alternative is selected.

Delivery Protocol

As no Reclamation or MID conveyances to Madera Ranch would be upgraded under this Alternative, MID would not be able to recover banked water for conveyance to MID's users or other bank participants.

In order to implement this Alternative, MID would need to enter into a wheeling agreement with Reclamation using San Joaquin River Restoration water. Under this scenario, in years when water is available for banking, it would be wheeled through the San Joaquin River and then the GF Canal and banked at Madera Ranch. In years when the water is needed by MID, it would be recovered from wells and allowed to flow back through the GF Canal to the San Joaquin River. MID's releases of recovered water to the San Joaquin River would be used as San Joaquin River Restoration flows in exchange for deliveries of San Joaquin River Restoration water from Millerton Lake to Madera Ranch water bank participants.

These deliveries would be made in lieu of normal surface water deliveries from Millerton Lake or Hensley Lake. Therefore, an equal volume of water would be made available to MID from these reservoirs for delivery to other parts of the MID service areas, increasing the net supply of available water.

Water Recovery Operations

Water would be recovered using existing wells and new wells installed in the vicinity and downgradient of the recharge areas. As noted above, recovery operations would be constrained by the MOCP to prevent unacceptable impact on surrounding landowners. Recovered water would be pumped into collection piping and into the GF Canal for delivery to the San Joaquin River. Recovered water would be delivered through exchange agreements as discussed above in the Delivery Protocol subsection of Alternative D.

The recovery operations described above do not depend on farmer irrigation demand but would depend on the schedule of required flows for San Joaquin River restoration, which may not match banking participant needs.

Use of the Water Bank Facilities by Other Entities
Please refer to the Use of the Water Bank Facilities by Other Entities subsection of Alternative B.

Mitigation
MID would revise its mitigation commitments under this alternative. Mitigation anticipated for Alternative D could be less than approximately 4,500 acres depending on the number of acres of recharge basins constructed. MID's conceptual mitigation areas would include a portion of the areas illustrated in Figure 2-12.

2.7 Environmental Commitments

The following environmental commitments would be implemented where applicable, in association with construction activities for the alternatives The environmental commitments section was developed by Reclamation and MID in coordination with the Corps and USFWS. Each commitment would be implemented in accordance with each agency's policies, guidance, and authorities. Additional detail on the environmental commitments is in the Affected Environment and Environmental Consequences section.

Table 2-2 Environmental Commitments

Identifier	Environmental Commitment	Commitment Specifications
Agriculture		
AG-1	Permanently Preserve Farmland by Establishing a Conservation Easement on Agricultural Land	MID will establish conservation easements on agricultural land at an effect-to-mitigation ratio of 2:1 to prevent permanent conversion of the land to urban uses and to increase farm viability. This mitigation will be in kind and used to mitigate the loss of farmland classified as prime farmland or farmland of statewide importance.
Air Quality		
AQ-1	Implement San Joaquin Valley Air Pollution Control District Regulation VIII Control Measures for construction emissions of PM10.	• All disturbed areas, including storage piles, that are not being actively used for construction purposes will be effectively stabilized against dust emissions using water, chemical stabilizer/suppressant, or vegetative ground cover. Chemical stabilizer/suppressants will not be used near waters of the United States. • All on-site unpaved roads and off-site unpaved access roads used during construction will be effectively stabilized against dust emissions using water or chemical stabilizer/suppressant. • All land-clearing, grubbing, scraping, excavating, land-leveling, grading, cut-and-fill, and demolition activities will be effectively controlled against fugitive dust emissions by applying water or presoaking. • All operations will limit or expeditiously remove the accumulation of mud or dirt from adjacent public streets at least once every 24 hours during operations (The use of dry rotary brushes is expressly prohibited except where preceded or accompanied by sufficient wetting to limit visible dust emissions. The use of blower devices is expressly forbidden.). After materials are added to or removed from the surface of outdoor storage piles, the piles will be effectively stabilized against fugitive dust emissions using sufficient water or chemical stabilizer/suppressant.
AQ-2	Reduce Emissions Associated with Idling Equipment	Per California Air Resources Board regulations (Title 13 of the California Code of Regulations, Sections 2480 and 2485), which limit idling of diesel-fueled commercial motor vehicles, MID will require that all diesel engines be shut off when not in use to reduce emissions from idling.
AQ-3	Use Electric Pumps	MID will use as many electric pumps as possible for recovery operations to reduce emissions associated with propane. If propane pumps are needed, MID will use engines with catalytic controls and that meet SJVAPCD best available control technology (BACT) requirement for engines over 50 hp.
Biological Resources		
BIO-1	Establish a Grasslands Conservation Easement	Mitigation for the loss of California annual grassland, alkali grassland, or Great Valley iodine brush scrub would consist of establishing a grasslands conservation easement at Madera Ranch over an area of habitat larger than the area subject to long-term degradation (2 acres conserved: 1 acre affected for swales) or permanent loss (3 acre conserved: 1 acre lost). MID also would implement a Madera Ranch Mitigation, Grazing, and Management Plan to improve existing on-site habitat through grazing management and species monitoring. This measure would compensate completely for the loss of these habitats.
BIO-2a	Preconstruction Surveys/Avoid Effects on Vernal Pools and Alkali Rain Pools	MID will minimize effects on species in this habitat by avoiding these wetlands to the extent practical. A buffer area will be established around suitable habitat for listed crustaceans in the action area, i.e., vernal pools. Buffer areas will be demarcated by installing fencing 250 feet from each occupied pool. A qualified biologist will flag the pools to be fenced, and temporary fences will be installed as the first order of work. Construction barrier fencing will be placed at the edge of the buffer areas. Temporary fences will be furnished, constructed, maintained, and later removed as shown on the construction plans, as specified in the special provisions, and as directed by the project engineer. Temporary fencing will be four feet high, orange, commercial-quality woven polypropylene. No construction activities will be permitted within the buffer zone (including staging or sidecasting of material) other than those activities necessary to erect the fencing. Erosion control measures will be employed adjacent to occupied listed crustacean habitat to prevent soil from eroding or falling into these areas. Natural/ biodegradable erosion control measures (e.g., straw wattles, hay bales) will be used. Plastic monofilament netting (erosion control matting) will not be allowed.
BIO-2b	Create, Restore, and/or Preserve Vernal Pools	MID will create, restore and/or preserve vernal pool habitat at Madera Ranch in an area protected under a conservation easement. Five acres of vernal habitat would be restored and/or preserved for each acre of vernal pool or alkali rain pool habitat lost as a result of activities associated with the Proposed Action (5 acre created: 1 acre lost). MID anticipates that the approximate split of these acreages will be 3:1 preservation and 2:1 creation/restoration. This ultimately will be determined based on wetland locations, soil conditions, and consultation with the Corps; soils, hydrology, vegetation, and species will be monitored. The performance standard for created vernal pools is to ensure the new vernal pools emulate the natural pools at Madera Ranch. Created vernal pools would have similar plant species composition and vegetation cover and invertebrate fauna as the vernal pools that are being removed by activities associated with the Proposed Action. Success of the vernal pool creation would be assessed by comparing the pools with undisturbed natural vernal pools at Madera Ranch. Restored vernal pools will have similar success criteria. This mitigation would compensate for the loss of vernal pool habitat. Restoration is more likely to be successful in areas with degraded habitat and where preservation is the most assured. In addition, MID will comply with Reclamation's wetlands mitigation and enhancement policy, which focuses on protecting, restoring, and enhancing wetlands and ensuring no overall net loss of wetlands. Wetland mitigation creation and restoration sites will be monitored until it is proven successful to the Corps, USFWS, and DFG. Mitigation sites must function for at least three years without human intervention.
BIO-3a	Avoid Effects on Iodine Bush Scrub	MID will locate the well and pipeline to avoid direct effects on iodine bush scrub habitat in the northern portion of Section 7 associated with construction activities. If wells and pipelines need to be constructed in this habitat, MID will conduct botanical surveys and mark plants to be avoided during construction.
BIO-3b	Survey for Sensitive Plants	During Phase 1, two botanists conducted visual surveys for palmate-bracted bird's beak (*Cordylanthus palmatus*) and other sensitive plant species along a 60-foot corridor (30 feet per side) along the proposed pipeline and canal alignments and in the swales east of Gravelly Ford Canal. The surveys were conducted in April and July and reference populations were visited. No listed species were found and sensitive *Atriplex* species were mapped to minimize future effects. The results of the botanical surveys will be used to determine which avoidance, minimization, and environmental commitments will be employed. During Phase 2, additional botanical surveys will be conducted in the area proposed for recharge basin creation. Complete visual surveys will be conducted in a similar manner in all areas proposed for permanent ground disturbance. If palmate-bracted bird's beak is found, the population will be delineated with highly visible flagging tape or plastic fencing and avoided. If other sensitive species are found, MID, DFG and USFWS will coordinate to determine the feasibility of avoiding the population.
BIO-4a	Preconstruction Surveys for California Tiger Salamander	A USFWS-approved biologist will conduct preconstruction surveys for California tiger salamander (*Ambystoma californiense [=A. tigrinum c.]*) in suitable aquatic and upland habitat. Before the start of ground-disturbing activities or vegetation removal, the approved biologist or biological monitor will survey the area to be affected that day for California tiger salamanders. The biologist also will examine any open trenches, which will have ramps or be closed when unattended, for the presence of salamanders. If a salamander is found in the construction area, the approved biologist will remove the animal from the area and release it into a suitable burrow at least 300 feet outside the construction area. The biologist will document the results of surveys on preconstruction survey log sheets, which will be kept on file at MID.
BIO-4b	Restrict Construction Activity in Suitable Aquatic and Upland Habitat for California Tiger Salamander to the Dry Season (April 1–November 1)	To avoid and minimize potential mortality and injury of breeding and dispersing California tiger salamanders, construction will take place only during the dry season (between April 1 and November 1 or before the onset of the rainy season, whichever occurs first) in suitable aquatic and upland habitat for the species. Upland habitat is defined as all habitat within one mile of occupied or suitable aquatic habitat. Specifically, this measure applies to all pipeline construction on Madera Ranch and during work at all delivery canals. This measure does not apply to construction activities in gravel shoulders and heavily disturbed non-habitat areas where construction is confined entirely to areas devoid of upland grassland habitat.
BIO-4c	Fence the Construction Zone and Implement Erosion Control Measures	The construction zone will be fenced in areas where suitable aquatic habitat for California tiger salamander is adjacent to the construction area. The purpose of the fence is to restrict construction equipment to the designated area only. Erosion control measures also will be implemented in these areas to prevent any soil or other materials from entering aquatic habitat. Locations of temporary

Identifier	Environmental Commitment	Commitment Specifications
	in Areas Where Suitable Aquatic Habitat for California Tiger Salamander Is Present	fences and erosion control measures will be shown on the construction plans and will be reviewed by a qualified biologist. Construction barrier fencing will be installed along the edge of the work area as the first order of work. Temporary fences will be furnished, constructed, maintained, and later removed as shown on the plans, as specified in the special provisions, and as directed by the project engineer. No construction activities will be permitted outside the designated construction zone other than those activities necessary to erect the fencing. Erosion control measures will be installed adjacent to suitable aquatic habitat to prevent soil from eroding or falling into these areas. Natural/biodegradable erosion control measures (e.g., straw wattles, hay bales) will be used. Plastic monofilament netting (erosion control matting) will not be allowed because salamanders can be caught in this type of material.
BIO-5	Pre-Activity Surveys for Blunt-Nosed Leopard Lizard	The objective of the blunt-nosed leopard lizard (*Gambelia [=Crotaphytus] sila*) (blunt-nosed leopard lizard) surveys is to avoid take of blunt-nosed leopard lizard during use of the swales for water banking and construction of water delivery canals and other facilities. Specific measures for linear facilities and swales are described below.
Bio-5a	Install exclusion fencing and conduct clearance surveys and construction monitoring for blunt-nosed leopard lizards	*Linear Facilities* Prior to construction of linear facilities in grassland and/or saltbush scrub/Valley sink scrub habitat and adjacent dirt roadways MID, in consultation and coordination with qualified wildlife biologists, shall create exclusion corridors based on habitat suitability and the need to create exclusion zones for burrows, scalds, and wetlands. Construction of linear facilities is restricted to May 1st through August 1st and may commence in areas only after Blunt-Nosed Leopard Lizard (—BNLL”) pre-construction surveys are completed. Pre-activity BNLL surveys were coordinated with the USFWS and CDFG since California's Fish and Game Code does not allow take of this species. Pre-activity surveys shall consist of the following minimum parameters: 1. Surveys for adult BNLL shall be conducted between April 28th and July 1st and shall occur when the air temperature (as measured at 1-2 cm above the ground over a surface most representative of the area being surveyed) is between 25 °C - 35 °C (77 °F – 95 °F). Once the air temperature falls within the optimal range, surveys may begin after sunrise (once sun is high enough to shine directly on the ground surface being surveyed) and must end by 1400 hours or when the maximum air temperature is reached, whichever occurs first. 2. Time of day and air temperature shall be recorded at the start and end of each survey. 3. Surveys will not be conducted on overcast (cloud cover > 90%) or rainy days or when sustained wind velocity exceeds 10 mph (>3 on Beaufort wind scale). 4. Surveys shall be conducted on foot and transects shall be no larger than 10 meters wide, consist of a slow pace, and be conducted on a north-south orientation when possible. 5. Surveys shall be conducted for 12 days over the course of a 30 day period. Surveys shall be conducted for 4 consecutive days, weather permitting with at least one survey session consisting of a 4 consecutive day period. 6. The starting/ending locations of surveys should be modified/alternated to the extent practicable, but resulting in the same area surveyed. This is so that different portions of the site are surveyed at different time/temp periods. 7. Surveyors must be approved by the DFG and USFWS to conduct the BNLL reconnaissance surveys. The survey crew conducting focused BNLL surveys shall consist of no more than 3 Level I surveyors for every Level II surveyor. The names of every surveyor must be recorded for each survey day. 8. All herpetofauna observations shall be recorded/tallied. All BNLL observations shall be recorded with GPS, time of observation, name of observer, sex (if evident), and lifestage (adult, juvenile, hatchling). If BNLL is observed in association with or observed entering a particular burrow, burrow location (via GPS) should be recorded as well. 9. If a BNLL is observed within such areas, consultation with CDFG must immediately occur. However, if BNLL observations are made, BNLL surveys should not be halted; the entire survey should be completed for the entirety of the construction footprint; continuing the surveys is important to maximize detections and to best help inform where the lizards occur and may not occur. Partial surveys cannot be used to inform whether or not avoidance can or will occur. (hereafter 1- 9 collectively referred to as, —BNLL Pre-Construction Survey Parameters”.) A. <u>Installation of Barrier</u> - Within 3 days after BNLL pre-construction surveys are completed, biologists shall oversee the creation an exclusion area by installing a non-gaping non-climbable barrier using a material approved by DFG and the USFWS along 3 sides of the planned linear facility construction perimeter. The barrier installation shall be overseen by biologists who have BNLL experience and who have been approved in advance by USFWS and DFG (hereafter, qualified BNLL biologists). The barrier fencing shall be installed perpendicular to the ground (vertical) and shall be sealed to ensure there are no gaps between segments or under the fencing. An example of possible suitable material can be found at http://www.ertecsystems.com/. Small mammal burrows and burrow complexes shall be excluded from the liner facility construction areas to the maximum extent practicable and a no disturbance buffer zone shall be established and clearly delineated from any burrows / burrow complexes. The day following the installation of the fencing, the qualified BNLL biologists shall walk approximately 10 meter transects along the partially fenced linear facility construction area during the time of day when air temperatures fall within the optimum range for species detection, during the peak BNLL activity season, and as outlined above. If no BNLL are detected, the fourth side of fencing may be installed and MID may begin work within the fenced area. At least two DFG and USFWS approved biologists will be present within the construction area when construction and other activities within the exclusion area are in progress. B. <u>Walking Surveys Throughout Construction</u> - Throughout construction, the biologists shall conduct walking surveys of the construction area, looking for BNLL. All open holes and trenches within habitat will be inspected at the beginning of the day, middle of the day, and end of day for trapped animals. If BNLL are detected at any time and within any area of the basin construction site, biologists will halt all work, open a section of the exclusion fencing, and allow the lizard to leave the area on its own (no chasing, following, etc. can occur). C. <u>Inadvertent Entrapment Prevention</u>-- To prevent inadvertent entrapment of BNLL or any other wildlife during the construction phase of the linear facilities, all excavated, steep-walled holes or trenches more than 2 feet deep shall be covered at the close of each working day by plywood or similar materials or provided with one or more escape ramps (with no greater than a 3:1 slope) constructed of earth fill or wooden planks. Before such holes or trenches are filled, they shall be thoroughly inspected for trapped animals by a qualified biologist. If BNLL are trapped, then it shall be allowed to escape on its own. In addition, all construction pipe, culverts, or similar structures with a diameter of 7.6 centimeters (3 inches) or greater that are stored at the construction site for one or more overnight periods will be thoroughly inspected for BNLL before the pipe is subsequently moved, buried, or capped. If during inspection one of these animals is discovered inside a pipe that section of pipe shall not be moved until the animal has escaped on its own. D. <u>Construction Time</u> - The permitted construction time is from one hour after sunrise to one hour before sunset, and two biological monitors shall also be active at all times when construction or other activities are in progress. The biological monitors shall survey the construction area during construction, scanning the ground for BNLL and routinely checking excavated soils to ensure that BNLL are not present. The biological monitors shall stop work if a lizard is found within the construction area until the lizard has been excluded from the work area. E. <u>Multiple Construction Areas</u> More than one linear facility construction area may be established and under construction at the same time provided the minimum number of biologists and biological monitors are present at each of the sites at all times during construction or other related activities.

Identifier	Environmental Commitment	Commitment Specifications
		F. <u>Notification of Dead or Injured BNLL</u> - If any dead or injured BNLL are observed on or adjacent to the construction site, or along haul roads/travel routes for worker and/or equipment, regardless of assumed cause, DFG and USFWS shall be notified. The initial notification to DFG and USFWS shall include information regarding the location, species, and the number of animals injured or killed. Following initial notification, MID shall send DFG and USFWS a written report within 2 calendar days. The report shall include the date and time of the finding or incident, location of the carcass, and if possible provide a photograph, explanation as to cause of death, and any other pertinent information. G. <u>Fully Protected Species</u> - These measures shall not be required if the species' fully protected status is rescinded and MID obtains incidental take authorization from DFG for this species for this project. *Recharge Basins* MID, in consultation and coordination with qualified wildlife biologists, shall create appropriately sized recharge basin construction areas before construction of recharge basins in grassland and/or saltbush scrub/Valley sink scrub habitat and adjacent dirt roadways within the former center pivot areas of Section 16, 17, and 18 on Madera Ranch. Construction areas shall be prioritized initially by reconnaissance surveys no more than 60 days prior to any basin construction activities or ground disturbance to identify areas with the fewest burrows and least suitable habitat for BNLL. Construction of basins will be restricted to May 1st through August 1st and may commence in areas identified through the above referenced reconnaissance surveys only after BNLL pre-construction surveys are completed by way of the BNLL Pre-Construction Survey Parameters (See paragraph I.A. above). The information gathered from these surveys will be used by DFG to determine which habitat is most likely occupied and to identify appropriate exclusion areas. (Basins shall initially be planned to be sited in the former center pivot areas of Section 16, 17, and 18.) If no BNLL is observed within 3 days after the completion of the BNLL pre-construction survey, biologists shall create an exclusion area by installing non-gaping non-climbable barrier. The installation for such barrier shall comply with the installation guidelines listed above under linear facilities, and must be supervised by a qualified BNLL biologist. (See paragraph I.B above.) Construction of the recharge basins is permitted from one hour after sunrise to one hour before sunset. (See I.E above.) More than one percolation basin construction area may be establish and under construction at the same time provided the minimum number of biologists and biological monitors are present at each of the sites at all times during construction or other related activities. Throughout construction, Biologists shall conduct walking surveys of the construction area to determine whether there is any detection of the BNLL. The survey procedures shall comply with paragraph I.C. listed above. Also during construction, all excavated, steep-walled holes or trenches more than 2 feet deep shall be covered as described under I.D above, to prevent inadvertent entrapment of BNLL or any other wildlife. Finally, if any dead or injured BNLL are observed on or adjacent to the construction site, then MID must notified DFG and USFWS in accordance with the outline procedures listed above under I.G. If the BNLL fully protected status is rescinded and an incidental take permit is granted, then these measures will not be required. *On-Ranch Ground Disturbing Facility Maintenance* MID will have an agency approved biologist review future ground disturbing facility maintenance work locations and sizes to evaluate the potential for effects to BNLL. If the activity is in suitable habitat and could affect burrows, MID will conduct the work during the appropriate seasonal window and implement site-specific exclusion measures such as fencing and additional surveys as prescribed above for linear facilities.
Bio-5b	Conduct blunt-nosed leopard lizard and burrow surveys of swales proposed for inundation	MID will conduct BNLL and burrow surveys of swales prior to inundation in swales. Those portions of swales that have been inundated annually for extended periods prior to Project approval will not be surveyed because potential burrows likely have been inundated and eroded, and BNLL are unlikely to aestivate in these areas. Pre-wetting BNLL surveys will be consistent with the *BNLL Pre-Construction Survey Parameters* listed above under I.A.. The information from these surveys will be used to determine which habitat is most likely occupied and to identify appropriate swale use areas. If no BNLL are found during the surveys, water may be applied throughout that following year. If a BNLL is sighted within the low point of a swale (i.e., the expected inundation area) it will be difficult to determine whether the burrows in the area are being used for nesting or refugia. Therefore, MID will delay using the swale for banking until the active season (April 28 to July 1); then MID will apply water to the swale slowly (i.e., approximately 12 inches per minute) to ensure lizards can escape burrows. These measures shall not be required if the species' fully protected status is rescinded and MID obtains incidental take authorization from DFG for this species for this project.
Bio-5c	Implement other protective measures for blunt-nosed leopard lizard	MID will implement other protective measures for blunt-nosed leopard lizard. MID would create at least three canal crossings along Gravelly Ford Canal and 6 canal crossings along the Section 8 Canal Northern Extension; the width of the crossings will vary from approximately 16 feet along Gravelly Ford Canal to approximately eight feet along the Section 8 Canal Northern Extension. While making Gravelly Ford Canal improvements and installing the Section 8 Canal Northern Extension, MID would excavate slightly below the bottom grade of the canal to install a culvert and provide for a crossing to connect the habitat units. The area would be backfilled, covering the crossing with soil from the canal improvement. A similar concept would be employed for the Section 8 Canal Northern Extension, though the length of the pipe segment would be four to eight feet and because of the flat hydraulic grade one larger pipe may be used. Additionally, on-ranch canal side slopes will be designed to allow BNLL to avoid entrapment.
BIO-6	Preconstruction Surveys and Avoidance Activities for Raptors	Preconstruction surveys would determine whether any sensitive raptors are nesting at Madera Ranch. If a tree is occupied at the time of construction, construction activities will be restricted to areas outside 0.5 mile of the tree. Setbacks will be marked with brightly colored temporary fencing.
BIO-7	Preconstruction Surveys for Western Burrowing Owl	The initial daytime burrow survey will help inform the Western burrowing owl (*Athene cunicularia*) survey. A qualified wildlife biologist will conduct a burrowing owl survey in accordance with DFG guidelines. The survey area will include the construction corridor and a 500-foot buffer. An initial survey will determine whether burrowing owls are present. Three additional surveys will be conducted to determine presence or absence of burrowing owls. In accordance with DFG survey guidelines, these surveys must be conducted on four separate days—two in the early morning and two in the late afternoon/early evening. Non-nesting owls may be passively relocated, also using DFG's guidelines.
BIO-8	Preconstruction Surveys for San Joaquin Kit Fox	Because of historical records and suitable San Joaquin kit fox (*Vulpes macrotis mutica*) habitat on or in the vicinity of Madera Ranch, it is assumed that kit foxes could be present at Madera Ranch. To avoid potential mortality of kit fox, agency approved (by USFWS and DFG) experienced biologists will survey to locate any natal dens, non-natal active dens, and/or potential dens in the Proposed Action area. Visual surveys will be conducted during meandering transects of the 1,000 foot corridor. If an active natal den is found, USFWS and DFG will be notified and MID will delay construction within 1,000 feet of the den until the pups have been weaned or moved to an off-site den, and/or reroute the construction corridor to avoid impacts on the kit foxes. Standard Kit fox provisions will be followed in accordance with USFWS guidelines.

Identifier	Environmental Commitment	Commitment Specifications
		Surveying will include meandering transect surveys for active dens (non-natal) out to 250 feet from the proposed facilities, which will involve simultaneous surveys for potential den sites out to 100 feet. If an active den is found, it will be avoided until the foxes have vacated the den. All potential dens will be flagged. Any potential den immediately in the construction corridor may need additional monitoring. Because construction is expected to proceed quickly—approximately 1,000 feet per day with trenches being open one to two nights—potential dens will not be collapsed. All surveys will be conducted within 30 days of site-specific construction by a qualified biologist. In addition, during construction, USFWS standard kit fox conservation measures such as speed limits, exit ramps, controlling toxic (oil or gas) spills from construction equipment, and covering pipes will be implemented to prevent harm or disturbance to kit foxes using the area. Any open pipes, newly dug pipeline trenches, and canals will be surveyed daily prior to construction to ensure kit foxes are not present.
BIO 9	Conduct Pre-Activity Surveys for Fresno Kangaroo Rat	The objective of the Fresno kangaroo rat (*Dipodomys nitratoides exilis*) surveys is to determine whether the Fresno kangaroo rat is present on the portion of Madera Ranch that could be affected by use of the swales for water banking and construction of water delivery canals. Initial trapping focused on the swales and canals east of GF Canal and determined the species was not present. Subsequent trapping will occur 1-year before use of swales or construction of facilities west of GF Canal. Surveys in swales will be conducted 1 to 2 years before the first wetting of the swale and will be valid for 5 years after the wetting of the swale. If the swale is re-wetted within the 5-year period, it will not need to be surveyed for another 5-year period. No additional survey efforts will be conducted of any swale areas that have been surveyed twice with neither survey resulting in a single trapping of the Fresno kangaroo rat. Kangaroo rat trapping efforts will be conducted by a surveyor holding a recovery permit for the Fresno kangaroo rat (10[a][1][A] permit). Meandering visual transect surveys for kangaroo rat burrow complexes and sign (e.g., tail drags, sand baths, seed caches) will be conducted by two to four biologists over all habitat within and out to 250 feet from the edge of the WSEP footprint, including swales, and within 100 feet of the top of GF Canal. All burrow complexes found will be recorded on a GPS unit, and data on the number of burrows, level of activity, and general suitability for kangaroo rats will be recorded in field notes (burrows suitable for kit fox also will be noted on GPS as part of this effort); information on vegetation type and percent cover also will be recorded. Following completion of the survey, potential trapping-sites will be prioritized based on a combination of the level of kangaroo rat activity (as evidenced by burrow density and/or the presence of other sign, though some areas without obvious sign may also be trapped) and project area coverage. Live trap stations and trap lines then will be established (staked and recorded with a GPS unit) by permitted biologists at the highest priority sites. Traps (Sherman live traps [Model XLKR: 13 inches x 3.5 inches x 3 inches]) will be set near active burrows, dust baths, or tracks, particularly along evident runways. Ten or more traps (or a number determined by the surveyor) will be set in relatively tight clusters (5-foot trap spacing) at high activity areas. Traps also will be set at 10 to 15 meter intervals (two traps per station) along evident movement corridors. Traps will be baited with a mixture of millet seed, crimped oats, wild birdseed, or other suitable seed. Bedding (crumpled unbleached paper towel) will be placed at the inside end of each trap and will not be allowed to contact the tripping mechanism. Paper towels will be replaced each time an animal is captured in the trap. Traps will be opened and baited at sunset and checked 1-2 times/evening as deemed appropriate by the lead biologist. All traps will be closed after they have been checked at dawn. Trapping will be conducted at each trap site for five consecutive nights. Trapping will not be conducted during the week of a full moon, unless the sky is overcast and moonlight is substantially reduced. Trapping will not be conducted in December or January or in periods of cold or inclement weather detrimental to kangaroo rats and as stipulated in the surveyor's recovery permit. Although Fresno kangaroo rats are active year round, their populations generally are lowest at this time. All non-Fresno kangaroo rats captured will be marked with a nontoxic semi-permanent ink marker on the belly to identify the re-trapping of the same animal(s). Trapping will cease with the capture of a Fresno kangaroo rat and MID, the USFWS, and DFG will be notified as soon as possible, if not the same day, then the next workday, or no later than the Monday following the capture should it occur on a Friday or Saturday night. Any measurements obtained to provide evidence that the animal captured is a Fresno kangaroo rat will be achieved with minimal and delicate handling fur and tissue samples will be taken only by a qualified, permitted biologist in accordance with their permit terms. A photo of the animal's hind legs (showing toes and including a ruler) will be taken and the animal will be immediately released; the animal's eyes will be shielded from the flash. The lead biologist will notify MID of the proposed trapping schedule and will inform MID weekly which trapping areas have been completed. Any capture of Fresno kangaroo rat will be reported immediately to MID, the USFWS, DFG, and Reclamation.
BIO-10	Conduct Preconstruction Surveys for Sensitive Species along the Off-Ranch Portion of Gravelly Ford Canal	Proposed off-ranch work areas associated with GF Canal improvements will be evaluated by a USFWS-approved biologist to determine whether habitat suitable to support sensitive species is present. If suitable habitat is discovered, MID will evaluate work locations to determine which species could be present and whether additional surveys may be needed. Depending on the results of this survey, MID also may implement Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement, Environmental Commitment BIO-5: Pre-Activity Surveys for Blunt-Nosed Leopard Lizard, Environmental Commitment BIO-6: Preconstruction Surveys and Avoidance Activities for Raptors, and Environmental Commitment BIO-7: Preconstruction Surveys for Western Burrowing Owl.
BIO-11	Implement Protective Measures for Anadromous Fish	MID would work with Reclamation and the National Marine Fisheries Service (NMFS) to determine appropriate protective measures for migratory fish once they are restored to the San Joaquin River, including seasonal restrictions on diversions or intake screening in the event water is moved to and from Madera Ranch via GF Canal (Alternative D). Inter-agency discussions would occur at least two years in advance of the reintroduction of these species to the San Joaquin River.
Cultural Resources		
CR-1	Stop Construction If Cultural Resources Are Discovered	In the event of any inadvertent cultural resources discovery, human or otherwise, uncovered during construction or other ground-disturbing activities, the construction contractor will immediately stop work in the immediate vicinity and a minimum 100-foot buffer area from the find. The contractor will notify MID immediately and MID will notify Reclamation of the inadvertent discovery. A professionally qualified archaeologist will be sent to evaluate the inadvertent discovery for National Register of Historic Places (NRHP) eligibility. If human remains are discovered during ground-disturbing activities, the party responsible for CEQA will comply with state laws[1] relating to the disposition of human remains pursuant to Public Resources Code (PRC) section 5097. Reclamation may have additional responsibilities under Section 106 of the NHPA and will follow the procedures in 36 CFR Part 800.13.
Geology, Soils, Seismicity and Erosion		
GEO-1	Amend Soils as Required in Topsoiled Areas	Topsoiled areas with insufficient vegetation cover will be amended with gypsum and/or elemental sulfur in combination with high-quality irrigation water to reduce soil salinity, alkalinity, and exchangeable sodium to acceptable levels, such that acceptable vegetation cover is established in such areas within one year after topsoil is applied. All soil sampling and amendment recommendations will be conducted by, or under the supervision of, a certified professional soil scientist.
GEO-2	Stop Work in Event of Fossil Discovery	In the event that a fossil or material that could be a fossil is unexpectedly discovered during excavation operations, work will cease in the immediate vicinity of the find. A qualified paleontologist will be called to the site to evaluate the find and determine the sensitivity of the fossil. If the fossil is determined to be sensitive, the paleontologist will recover it from the site and submit it to an appropriate

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[1] Madera Ranch does not include federal land, so only state human-remains laws apply.

Identifier	Environmental Commitment	Commitment Specifications
		museum or other repository for curation.
Hazards, Public Health and Safety		
PHS-1a	Implement Necessary Emergency Preparedness Plan(s)	MID will work with the Madera County Department of Public Health and the local fire districts to coordinate the preparation of emergency preparedness plan(s) that may be required by federal, state, and County statutes and regulations.
PHS-1b	Comply with Local Fire District Requirements	MID will consult the local fire districts to ensure that all regulations are complied with during construction.
PHS-2	Implement an Agreement with the Madera County Mosquito and Vector Control District	MID will enter into an agreement with the Madera County Mosquito Abatement & Vector Control District (MCMAVCD) regarding a specific mosquito abatement program. The agreement will allow the MCMAVCD to access Madera Ranch and also will include quantitative abatement thresholds and financial compensation requirements for MCMAVCD activities, if necessary. The MCMAVCD will monitor mosquito larvae production in the recharge basins, drainages, and distribution canals at no cost to MID, given that the amount of monitoring required is not excessive. Larvae populations will be tracked using methods and thresholds approved by the MCMAVCD, and suppression measures will be employed when thresholds are exceeded. Suppression measures may include environmental and biological methods, such as stocking mosquitofish, controlling emergent vegetation, and applying insecticides. Insecticide controls will be used only as a last resort, and use of insecticides over open water will be minimized to the extent feasible, given the mosquito abatement mandate of the MCMAVCD. The insecticides that may be used are only those that are approved for such uses by the U.S. Environmental Protection Agency (EPA). Mosquitofish, if used, will need to be stocked annually by the MCMAVCD. If operations result in an increase in mosquito production such that an extensive monitoring program is needed, MID will hire a professional pest control service and will bear the cost of that service.
Noise		
NOI-1	The construction contractor will employ noise-reducing construction practices so that noise from construction does not exceed County noise-level standards at adjacent residences.	Measures to be implemented would include the following. • Restrict construction to beyond 3,900 feet from residences during nighttime hours (10 p.m. to 7 a.m.). • Provide construction equipment with sound-control devices no less effective than those provided on the original equipment. No equipment will have an unmuffled exhaust. • Implement appropriate additional noise environmental commitments, including (but not limited to) changing the location of stationary construction equipment, shutting off idling equipment, rescheduling construction activity, notifying adjacent residents in advance of construction work, and installing acoustic barriers around stationary construction noise sources.
NOI-2	The construction contractor will employ noise-reducing methods during well drilling operations	The drilling contractor will employ noise-reducing construction practices so that noise from drilling does not exceed County noise-level standards at adjacent residences. Measures to be implemented may include those following. • Restrict well drilling to beyond 2,900 feet from residences during nighttime hours (10 p.m. to 7 a.m.), where feasible. • Use sound attenuation enclosures around noise-generating elements of the drilling operation.
NOI-3	The construction contractor will employ noise-reducing practices so that noise from well operations does not exceed County noise-level standards at adjacent residences.	Measures to be implemented may include: • restricting well installations to beyond 1,250 feet from residences, where feasible; • using electric pumps where well installations are within 1,250 feet of residences; and • using sound attenuation enclosures designed to achieve noise reductions sufficient to comply with County standards for noise-generating elements of the well operation when no other feasible control method is available.
NOI-4	The construction contractor will employ noise-reducing practices so that noise from lift station operations does not exceed County noise-level standards at adjacent residences	Measures to be implemented may include: • restricting lift station installations to beyond 1,600 feet from residences, where feasible; • using electric pumps where lift station installations are within 1,600 feet of residences; or • using sound attenuation enclosures designed to achieve noise reductions sufficient to comply with County standards for noise-generating elements of the lift station operation when no other feasible control method is available.
Public Services		
PSU-1a	Notify Emergency-Response Agencies of Proposed Traffic-Route Changes	Before beginning construction activities, MID or the construction contractor will contact local emergency-response agencies (law enforcement and fire protection) to provide information on the timing and location of any traffic control measures required during construction activities. Emergency-response agencies will be notified of any change to traffic control measures as the construction phases proceed so that emergency-response providers can modify their response routes to ensure that response time would not be affected.
PSU-1b	MID will require the construction contractor to prepare and implement a traffic safety plan (TSP) before the onset of construction activities.	The TSP will address: • appropriate vehicle size and speed, • travel routes, • detour or lane-closure plans, • flag person requirements, • locations of turnouts to be constructed, • coordination with law enforcement and fire control agencies, • coordination with California Department of Transportation (Caltrans) personnel (for work affecting state road rights-of way), • emergency access to ensure public safety, and • traffic and speed-limit signs.
Traffic		

Identifier	Environmental Commitment	Commitment Specifications
TRAF-1	MID will require the construction contractor to prepare and implement a road improvement plan (RIP) before the onset of the construction phase.	The RIP will identify road segments, bridges, and culverts that need to be improved and turnout locations that need to be constructed (as applicable) to accommodate construction activities. The plan also will identify damage that is caused by construction vehicles and that needs to be repaired.
Water Resources		
WQ-1a	Comply with National Pollutant Discharge Elimination System General Construction Permit	To reduce or eliminate construction-related water quality effects, before onset of any construction activities, MID or its contractor will obtain coverage under the National Pollutant Discharge Elimination System (NPDES) General Construction Permit. MID will be responsible to ensure that construction activities comply with the conditions in this permit, which will require development of a stormwater pollution prevention plan (SWPPP), implementation of best management practices (BMPs) identified in the SWPPP, and monitoring to ensure that effects on water quality are minimized. As part of this process, MID will implement multiple erosion and sediment control BMPs in areas with potential to drain to surface water (see Section 3.6, Geology, for a discussion of erosion and sediment control BMPs). These BMPs will be selected to achieve maximum sediment removal and represent the Best Available Technology (BAT) that is economically achievable. BMPs to be implemented as part of this environmental commitment may include, but are not limited to, the following measures. • Temporary erosion control measures (such as silt fences, staked straw bales/wattles, silt/sediment basins and traps, check dams, geofabric, sandbag dikes, and temporary revegetation or other ground cover) would be employed to control erosion from disturbed areas. • Drainage facilities in downstream off-site areas would be protected from sediment using BMPs acceptable to the Regional Water Quality Control Board (RWQCB). MID or its agent will perform routine inspections of the construction area to verify that the BMPs specified in the SWPPP are properly implemented and maintained. MID will notify its contractors immediately if there is a noncompliance issue and will require compliance.
WQ-1b	Implement a Spill Prevention and Control Program	MID or its contractor will develop and implement a spill prevention control and countermeasures program (SPCCP) to minimize the potential for, and effects from, spills of hazardous, toxic, or petroleum substances during construction activities for all contractors. The program will be completed before any construction activities begin. Implementation of this measure will comply with state and federal water quality regulations and minimize the effects of the Proposed Action. MID will review and approve the SPCCP before the onset of construction activities. MID will routinely inspect the construction area to verify that the measures specified in the SPCCP are properly implemented and maintained. MID will notify its contractors immediately if there is a noncompliance issue and will require compliance. The federal reportable spill quantity for petroleum products, as defined in the EPA's CFR (40 CFR 110), is any oil spill that (1) violates applicable water quality standards, (2) causes a film or sheen upon or discoloration of the water surface or adjoining shoreline, or (3) causes a sludge or emulsion to be deposited beneath the surface of the water or on adjoining shorelines. If a spill is reportable, the contractor's superintendent will notify MID, and MID will need to contact the appropriate safety and clean-up crews to ensure the SPCCP is followed. A written description of reportable releases must be submitted to the RWQCB. This submittal must include a description of the release, including the type of material and an estimate of the amount spilled, the date of the release, an explanation of why the spill occurred, and a description of the steps taken to prevent and control future releases. The releases will be documented on a spill report form. If a spill has occurred, MID will coordinate with responsible regulatory agencies to implement measures to control and abate contamination.
WQ-2	Implement Provisions for Dewatering	Before discharging any water from dewatering operations to surface water, MID or its contractors will obtain an NPDES permit and Waste Discharge Requirements (WDRs) from the RWQCB. Depending on the volume and characteristics of the discharge, coverage under the RWQCB's General Construction Permit or General Dewatering Permit is possible. As part of the permit, the permittee would design and implement measures as necessary so that the discharge limits identified in the relevant permit are met. As a performance standard, these measures will be selected to achieve maximum sediment removal and represent the BAT that is economically achievable. Implemented measures may include retention of water from dewatering operations until particulate matter has settled before it is discharged, use of infiltration areas, and other BMPs. Final selection of water quality control measures will be subject to approval by the RWQCB. MID will verify that coverage under the appropriate NPDES permit has been obtained before allowing dewatering activities to begin. MID or its agent will perform routine inspections of the construction area to verify that the water quality control measures are properly implemented and maintained. MID will notify its contractors immediately if there is a noncompliance issue and will require compliance.
Wetlands		
WET-1	Preservation of vernal pools and alkali rain pools.	Implementation of Environmental Commitments BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal and Alkali Rain Pools and BIO-2b: Create, Restore, or Preserve Vernal Pools would minimize the extent of and compensate for adverse effects.
WET-2	Reduction of impacts to Waters of the United States from the discharge of fill	In GF Canal there are seasonal wetlands, including approximately 2 acres of freshwater marsh that would be affected. These effects would be offset by the development of freshwater marsh within GF Canal during operation and formation of seasonal wetlands within the swales during banking.

Biological Opinion Commitments

On April 26, 2011, the USFWS issued a Biological Opinion to Reclamation (File Number 81420-2008-F-0279-1 (Appendix B) to address the impacts of Reduced Alternative B on Federally listed species. The following additional commitments (terms and conditions) are also imposed on Reduced Alternative B from the incidental take statement that was provided with the Biological Opinion.

1. Reclamation shall ensure through conditions in its approval letter or any funding for the proposed project that MID fully implements and adheres to the Environmental Commitments presented in the Biological Assessment and restated here in this Biological Opinion. These Environmental Commitments must be adhered to, regardless of species status under the California ESA.

2. Reclamation shall ensure through conditions in its approval letter for the proposed project the following Terms and Conditions:

    a) Reclamation shall ensure that MID grants and records an appropriate, USFWS-approved Conservation Easement with a USFWS-approved Conservation Easement holder for the mitigation lands described in the Biological Assessment, prior to project implementation.
    b) Reclamation shall ensure that MID incorporates by reference its Mitigation and Management Plan, developed for these mitigation lands, into said Conservation Easement.
    c) Reclamation shall ensure that MID includes language in the Conservation Easement stating that the Mitigation and Management Plan created for this project is a living document, to be viewed and used as an adaptive management plan under the direction and approval of the USFWS, DFG & Corps, with the goal of ensuring optimum habitat conditions for the species of concern.
    d) Reclamation shall ensure that MID has in place prior to project implementation an adequate, USFWS-approved funding mechanism, such as a non-wasting endowment held by a USFWS-approved endowment holder to fund the long-term management activities on their mitigation lands.

3. Reclamation shall ensure through conditions in its approval letter or any funding instrument for the proposed project that MID develops and implements an appropriate USFWS-approved hydrological study or studies, designed to monitor and report on conditions related to changing ecosystem characteristics in and adjacent to the swales used for water banking purposes. Such studies, and the information obtained from them, shall be used to inform Reclamation and MID of the degree and nature of habitat modification from current conditions, and whether take resulting from vegetative changes beyond the perimeter of water applications (i.e., greater than 20 percent) is exceeded. The information gathered from these studies shall be provided to the USFWS and DFG on thirty-day cycles or within thirty days of conclusion of a study cycle.

4. Reclamation shall ensure through conditions in its approval letter or any funding for the proposed project that MID develop a USFWS-approved monitoring and reporting

approach for the inundated swales and adjacent habitat sufficient to determine whether Fresno kangaroo rats and blunt-nosed leopard lizards re-colonize these areas during dry periods.

2.8 Environmentally Preferred Alternative

As described above, Reduced Alternative B, the Proposed Action is the preferred alternative. The No Action Alternative would not satisfy the purpose and need. In addition, groundwater overdraft would continue in Madera County. While Alternatives B, Reduced Alternative B, C, and D would facilitate growth that would not likely occur under the No Action Alternative, the No Action Alternative results in greater adverse effects on both water quality and water supply in Madera Ranch and the surrounding area. Alternative B, if fully built out would result in substantial effects to upland species and wetlands. Alternative C has reduced effects on wetland biological resources, a substantial effect on upland biological resources, and short-term increased effects on air quality. It is considered financially infeasible for MID as the cost outlay for 1,000 acres of recharge basins in Phase 1 of Alternative C does not give time for the bank to be operational prior to construction of basins (which under Alternative B and Reduced Alternative B banking within the swales would provide the financial ability to implement Phase 2). Alternative D reduces impacts on farmland of statewide importance relative to Alternative B, Reduced Alternative B, and C, and results in similar effects on biological resources relative to Alternative B. However, Alternative D includes the complication of having to operate the bank solely through water exchanges with the San Joaquin Settlement Water and could result in increased air quality effects during construction because of extensive additional canal construction along the off-site portions of GF Canal. While feasible, basing the bank on exchanges makes MID dependent on other agencies to receive water. Reliance on other agencies for water is not desirable, and the benefits of the alternative are not enough to compensate for this deficiency. In addition, it should be noted that Alternative D would rely on San Joaquin River restoration operations that have not yet been finalized and that may not come online within the time frame of desired Proposed Action implementation.

Given the elimination of the Section 8 canal southwest extension, reduction in the total number of swales used to minimize effects to wetlands, and identification of fewer basins to be constructed, Reclamation considers Reduced Alternative B to be the environmentally preferable alternative as well as the best overall alternative.

2.9 Alternatives Screening Process

The Draft EIS must present the environmental effects of the Proposed Action and alternatives in comparative form, sharply defining the issues and providing a clear basis for choice by decision-makers and the public (40 CFR 1502.14; Forty Questions No. 1).

The draft EIS must rigorously explore and objectively evaluate a reasonable range of alternatives along with the Proposed Action. Reasonable alternatives are those that feasibly may be carried out based on technical, economic, and environmental factors. Reclamation is not required to evaluate alternatives beyond the reasonable range of alternatives discussed in the environmental document. If alternatives have been eliminated from detailed study, the EIS must briefly discuss the reasons for their elimination (40 CFR 1502.14[a]; Forty Questions No. 1[a]).

The screening of alternatives starts with the statement of purpose and need, as identified in Chapter 1. In addition to the statement of purpose and need, Reclamation developed screening factors, based on cost, logistics, technology, social, environmental, and legal factors, that were considered in alternatives screening.

Typically, the development, evaluation, and selection of alternatives is a process in which Reclamation first lists a broad range of choices and then progressively narrows down the list to meet the purpose and need for action and feasibility factors. However, since the early 1990s the property has been conceived of for use as a groundwater bank, and an array of regional and site-specific alternatives has been considered. This information and past screening of viable approaches to water banking provide important context in the evaluation of alternatives and the reasoning that has led to the currently proposed alternatives. The screening process is described below following Background.

2.9.1 Background

Early project screening was conducted by former property owner Heber Perrett, Reclamation, California Department of Water Resources (DWR), former property owner Azurix Corporation, and MID. These groups explored a variety of alternatives, structural and nonstructural, throughout California. However, almost all of the proposed alternatives did not meet the objectives of a regional conjunctive-use groundwater bank in Madera County with an objective of increasing water supply reliability to MID farmers. Consequentially, these alternatives were not advanced as feasible alternatives because they failed screening as discussed below. Past alternatives considered and eliminated by these groups, including MID, included the following:

Water Conservation

Water conservation–related alternatives have limited potential to increase water supply reliability and reduce groundwater degradation in Madera County given the amount of water demand and size of the current and future overdraft anticipated. Water conservation is a component of all water management plans, but it is only one small component of voluntary and regulatory programs that are needed in Madera County (Madera County 2008).

Surface Water Storage

Surface water storage likely will be needed over the long term to address ongoing water supply and reliability issues throughout California and possibly in Madera County. However, there are few surface water storage options in Madera County that provide MID with necessary capacity to provide increased operational flexibility and groundwater overdraft protection. Furthermore, the surface water storage options are in the foothills, are likely to cost hundreds of millions of dollars, and are many years from obtaining water right entitlements and construction. The primary storage facility under consideration is Temperance Flat. This regional facility is still in the early planning phase and the cost required by MID and MID farmers would be substantially higher for a surface storage facility. Valley floor facilities are not feasible because of the limiting nature of geologic, topographic, and land use conditions in Madera County that eliminate the possibility of surface water storage.

Groundwater Banking in Other Areas

A variety of groundwater banking options in other areas was considered, including groundwater banking north of the Delta; groundwater banking in San Joaquin, Kern, or Fresno County; groundwater banking in other areas outside Madera County; and other groundwater banking sites in Madera County.

These alternatives were eliminated because of lack of existing water rights; lack of storage space in other areas; a substantial increase in water costs because of incurring storage and conveyance costs (see Water Transfers below); lack of contribution to groundwater overdraft protection in Madera County because there would be no recharge to the local aquifer; and significantly higher costs to construct a project on high-value land.

Water Transfers

Water transfers from imported water supplies likely would have to come from other CVP contractors. The CVP as a whole, like the Friant Division, is experiencing water supply reliability problems attributable to drought, water quality, and biological issues. Therefore, basing the project on water transfers would, in essence, be predicating achieving the purpose and need on long-term transfer agreements for another unreliable water supply. Water delivery through the Delta is constrained significantly per the 2008 BO on the Continued Operations of the CVP on CVP and State Water Project (SWP) operations.

In-Lieu Recharge

In-lieu recharge is a component of an overall water management program. Encouraging farmers to use surface supplies in-lieu of pumping groundwater would depend on the water year type and availability of the water supply, including a component of the water supply being available via banking or transfers. As described above, groundwater banking in other areas and water transfers are costly and do not meet the purpose and need. In-lieu recharge has limited potential to increase water supply reliability in Madera County and would increase the cost of conveyance to MID users if using out-of-area water.

MID's Alternatives

Previous screening as described above narrowed the range of alternatives to the use of the Madera Ranch property and potentially other locations in Madera County. However, as detailed below, other potential locations in Madera County were not found to be large enough, or underlain by sufficient banking space, to meet WSEP needs. Therefore, alternatives screening ultimately focused on alternative configurations and layouts for the project-specific facilities to minimize effects on biological resources while still meeting the objectives of the Proposed Action and the engineering design requirements.

The primary objective ~~is~~ to meet the need for additional storage and reliable and affordable water supplies for MID customers.” Accordingly, MID’s 2005 EIR alternatives analysis, which is incorporated by reference, was limited to Madera County. As such, a wide variety of potential water delivery and banking locations was evaluated in or adjacent to MID’s existing service area.

MID, through the 2005 EIR process, determined that only Madera Ranch offered sufficient areas of land with adequate groundwater recharge qualities, proximity to existing water conveyances, and available groundwater banking space to meet its identified objectives. Areas considered to be fatally flawed or impractical were screened out because of effects related to land use conversion, neighboring groundwater users, habitat, geohydrologic resources, and cost (Madera Irrigation District 2005).

MID developed alternatives based on the sources of water to be recharged, the capacities of the groundwater banking facilities, and the configuration of proposed facilities within the boundaries of Madera Ranch. Based on MID’s screening during the 2005 EIR process, two alternatives were carried forward for analysis in the EIR.

Alternative 1 in the 2005 EIR (previously proposed by Azurix) is an ―engineered” alternative that focused on the construction of percolation ponds and a large 12-mile delivery canal. It would require an approximately 3,000-acre area and use of both grassland and agricultural land. It would include a diversion site approximately one mile upstream of Mendota Dam on a portion of the San Joaquin River that receives water from the Bay-Delta. An intake channel and 12-mile-long canal would need to be constructed to convey the diverted water via three lift stations to Madera Ranch. The canal would be lined with concrete between the first pumping plant and Madera Ranch. MID did not select this alternative because of the environmental effects including those associated with using lower-quality water and removing agricultural land from production, and the higher cost associated with constructing the canal.

Alternative 2 in the 2005 EIR (MID’s Proposed Action, or Alternative B) would upgrade existing MID conveyances and add additional recharge areas and new recovery wells on the Madera Ranch property. These facilities would be used to bank San Joaquin River and Fresno River surface water and to recover the banked water when needed. The recovery of water would be limited to 90% of the amount recharged, thereby reducing the rate of overdraft of the underlying aquifer. MID would construct Alternative B in two phases.

A No Action Alternative (Alternative A), consisting of the sale and use of the property for other agricultural uses (e.g., dairies), also was analyzed.

2.9.2 Alternatives Screening

Alternatives that do not meet the purpose and need or cannot be technically implemented can be eliminated from detailed study, but the EIS must contain a description of the screening process used to exclude alternatives from the reasonable range. While Reclamation’s scope is fairly narrowly defined to include improvements to Reclamation’s facilities and banking outside MID’s service area, Reclamation is compelled under NEPA to review all potential alternatives to ensure that no feasible alternatives are capriciously excluded from consideration and analyze a reasonable range of alternatives. Viable alternatives brought forward for consideration in the NEPA process were evaluated using the following criteria.

- The alternative can meet the purpose and need;
- The alternative can be reasonably and technically implemented;
- The cost or environmental impacts would not be prohibitive.

Screening criteria against which all alternatives should be measured should include such items as cost limits, geographical boundaries, and meeting the purpose and need.

The study area for Reclamation was limited to the regional area of Madera County, primarily MID's service area, in order to meet the purpose and need. The range of alternatives for this alternatives analysis was not limited to the Madera Ranch property, as alternatives outside of Madera Ranch still have the potential to meet the purpose and need. The following alternatives were considered.

- Nonstructural alternatives, including water transfers and conservation.
- New recharge basins on Madera Ranch within MID service area.
- New recharge basins on other properties (i.e., not on Madera Ranch) within MID service area.
- A Mendota Pool–supplied project (the Azurix project).
- Injection well recharge.
- Expansion of MID's delivery facilities.
- The Proposed Action with swale recharge only.
- Other users of the bank for storage.
- Reduced recharge basin options.

Each of these alternatives is described below.

Alternatives Considered but Eliminated from Further Consideration

Nonstructural Alternatives, Including Water Transfers and Conservation The groundwater overdraft situation in Madera County is so dire that many techniques and projects will need to be implemented to meet future agricultural and urban water demand (Madera County 2008). Water transfers and conservation are being explored and implemented by various water districts as part of a comprehensive county-wide water management approach. However, the yield from these projects is small compared to MID's needs, these approaches do not result in additional dry-year banking capacity to support a reliable water supply, and these projects contribute only a small amount to reducing groundwater overdraft (Madera County 2008). MID, Madera County, and other local irrigation and water districts will continue to implement transfer and conservation efforts, but this alternative would not meet MID's objectives or Reclamation's purpose and need and would not be reasonable to implement.

New Recharge Basins on Madera Ranch within MID Service Area This alternative would involve the creation of recharge basins on portions of Madera Ranch within MID's service area (Figure 2-1). This alternative was rejected for two key reasons.

1. Soils on Madera Ranch within MID's service area are not appropriate to allow for sufficient recharge and would require an additional 1,000 acres of recharge area on properties along the eastern edge of Madera Ranch (Bookman-Edmonston 2003).
2. Construction of ponds on Madera Ranch in MID's service area would require conversion of 1,600 acres of prime agricultural lands on Madera Ranch and another 1,000 acres of

prime agricultural lands on adjacent properties in MID's service area; this would results in effects that are contrary to MID's mission of providing water to farmers by removing existing agricultural lands from production and would require substantial additional capital expenditures. It does not meet MID's objectives or Reclamation's purpose and need, and cannot be reasonably implemented.

New Basins on Other Properties within MID Service Area This alternative would involve the expansion of MID's existing recharge ponds and/or construction of new recharge ponds on other properties within MID's service area. MID's existing recharge ponds are not large enough to meet the required recharge needs and could not meet the recharge needs even if expanded. The key reason the use of other properties was rejected is that other sites with permeable soils cannot achieve the 55,000 AF/year volume anticipated at Madera Ranch. Madera Ranch is relatively large and is in a key location near the end of MID's service area and conveyance facilities. The Madera Ranch property also has a smaller number of adjacent groundwater users compared to the majority of MID's service area, which reduces the risk of infiltrated water being withdrawn by adjacent users. Use of other sites for recharge also would require conversion of prime agricultural lands, thus resulting in increased agricultural effects. Acquisition necessary to implement this alternative would require substantial additional capital expenditures and be cost-prohibitive for MID under current market conditions.

Mendota Pool Supplied Project The Mendota Pool Supplied Project (the Azurix project) was one of the alternatives analyzed by MID in its 2005 EIR. This alternative would consist of a combination of distribution system improvements and groundwater recharge conducted using engineered recharge basins constructed on the portions of the Madera Ranch property where active cultivation currently exists. The water supply for the alternative would be Bay-Delta CVP water from Mendota Pool. The diversion site would be approximately one mile upstream from Mendota Dam. An intake channel and 12-mile-long canal would need to be constructed to convey the diverted water via three lift stations to the Proposed Action area. The canal would be concrete-lined between the first pumping plant and Madera Ranch. In order to finance the acquisition of land for the new canal and finance construction of the engineered recharge basins, the project would require double the capacity of the Proposed Action and would require non-local participation to facilitate the water transfers necessary to acquire water from Mendota Pool. MID does not hold water rights to water in Mendota Pool and therefore would be required to enter into long-term transfer and exchange agreements with third parties such as the San Joaquin River Exchange Contractors to make water available for banking. In addition, the project would not include conveyances for direct delivery of recovered water into MID. Rather, it would rely on the following chains of exchanges and transfers to enable delivery of banked water back to MID.

- Banked water would be recovered from Madera Ranch and pumped back to Mendota Pool for use by others such as the San Joaquin River Exchange Contractors in lieu of their normal Delta-Mendota Canal deliveries.
- The equivalent volume of water now made available in the Bay-Delta would be conveyed through the California Aqueduct to the southern part of the Central Valley and delivered to a southern Friant Division contractor in lieu of its normal Friant deliveries, making an

equivalent volume of water available in Millerton Reservoir available for delivery to MID farmers.

- As analyzed in MID's 2005 EIR, water quality in Mendota Pool is of substantially lower quality compared to MID's Friant Division and Hidden Unit contract supplies and compared to the existing groundwater quality beneath Madera Ranch. For this reason, the MROC, the committee responsible for monitoring the operations of the WSEP, requires prior approval before any use of Mendota Pool water by a vote of nine consenting, with no dissenters among the 10-person committee. This requirement, as well as concerns regarding water quality and cost of constructing a new 12-mile canal, resulted in MID determining that this alternative does not meet the purpose and need. In addition, for MID to physically receive water from this configuration for its farmers, MID would be required to perform a complex set of exchanges and transfers with SWP and Southern Friant Contractors, resulting in reduced reliability due to uncertainties associated with long-term availability of pumping capacity in the Delta, as well as delivery capacity in other conveyances not controlled by MID and long-term willingness of several third parties to perform exchanges and transfers. This alternative would not meet the screening criteria for Reclamation as the alternative is prohibitively greater in cost and in environmental impacts than the other alternatives, and the alternative cannot be reasonably implemented.

Injection Well Recharge This alternative would achieve recharge directly using injection wells rather than swales and basins as proposed by MID. This alternative does not satisfy MID's purpose and need because of costs and technical and logistical issues. Similarly, Reclamation eliminated this alternative from further analysis because of its technical infeasibility and high costs compared to the cost of other feasible alternatives. Recharge using injection wells would pose the following significant challenges (Schmidt 2009).

- Injection wells typically accept water at lower rates than they can pump. Assuming that the Proposed Action (Alternative B) planned project wells are configured for both injection and recovery, Schmidt (2009) estimated that an additional 60 injection wells would be required to attain a recharge rate of 200 cfs. Injection wells require a higher quality of construction, instrumentation, and control than pumping wells. Taken together, Schmidt (2009) estimated that use of injection wells would increase well field capital costs by at least 50%. This increase in costs does not include the significant additional piping and a regulation reservoir that also would be required.
- Water would require treatment before injection to remove air, suspended particulates, bacteriological constituents, nutrients, organic constituents, and algae that would clog the wells, clog the geologic formation the water is injected into, and degrade groundwater quality. In addition, treatment may create trihalomethanes. Schmidt (2009) estimates that a 130-million gallon per day (MGD) treatment plant would be required, with capital costs ~~in~~ the hundreds of millions of dollars." MID does not have the staffing or equipment to operate a treatment plant and would be required to invest millions of dollars to obtain this functionality. It also should be noted that operation of the treatment system would generate solid wastes requiring disposal.

- A high degree of expertise and operational infrastructure that MID lacks would be required to successfully operate and maintain injection wells over the long term, significantly increasing project operations and maintenance (O&M) costs. Schmidt (2009) estimated that injection wells would increase O&M costs by approximately $2.4 million dollars per year. This O&M estimate does not include O&M costs associated with the treatment plant.
- Surface-based recharge systems can last indefinitely with appropriate maintenance. However, even with treatment systems and the facilities summarized above, the useful life of injection wells would be no more than 30 years, resulting in a need for MID to incur periodic replacement costs.

Taken together, use of injection wells would increase WSEP capital costs by hundreds of millions of dollars, increase O&M costs by millions of dollars per year, provide uncertain performance, and require a complete reinvention of MID’s O&M staffing and equipment resources. Schmidt (2009) reviewed numerous water banking and recharge projects throughout the Central Valley and found that injection wells were not selected for any of the projects for the variety of reasons summarized above.

Expansion of MID’s Delivery Facilities This alternative would involve the expansion of delivery facilities, including widening, deepening, and constructing new canals within MID’s service area to attain storage, recharge, and conveyance goals. This would allow MID to move their water allocation to users more effectively without requiring additional banking. MID could further enlarge the Section 8 Canal and also use Cottonwood Creek, which would contribute a small amount to groundwater recharge. However, the groundwater overdraft situation in Madera County is so dire that canal expansion and extensions would not reduce this problem; many techniques and projects, including conveyance projects, would need to be implemented to meet future agricultural and urban water demand (Madera County 2008). More importantly, this alternative would not meet MID’s needs, as it would not provide sufficient banking to enable provision of water to users in dry years because the recharge amounts would be small. This alternative was not advanced for technical reasons and because it does not meet the overall purpose and need.

The Proposed Action with Swale Recharge Only This alternative would be similar to the Proposed Action, but would rely solely on the swales to put water into the bank. This alternative assumes that engineered recharge basins would not be needed. This alternative could meet the purpose and need. MID has proposed retaining the recharge ponds to ensure the alternative remains technically feasible and acceptable from a regulatory perspective. Extensive pilot testing indicates that the identified swales could provide the required recharge capacity, but the long-term performance is uncertain. Additionally, controversy remains regarding the use of the swales relative to biological impacts because of the uncertainty of these effects on endangered species. Therefore, in order to provide certainty that the project can meet objectives, MID is obligated to contemplate Phase 2 recharge basins as a back-up in the event that the swales cannot provide the required long-term performance. A swale-only alternative provides a reduction in biological effects associated with grassland conversion and a reduction in air quality effects from construction of the ponds. However, as described above, other biological resources could be adversely and unacceptably affected by use of the swales. Because there is still some question regarding its feasibility and because of existing concerns by the USFWS and DFG, it was eliminated according to Reclamation's screening criteria.

Other Users of the Bank for Storage MID's Proposed Action identifies agricultural users with 64% of the bank's annual operational capacity; industrial, commercial, and residential users with 18% of the capacity; and environmental users with 18% of the capacity. Under an Other Users alternative, the percentage of capacity used for urban or environmental purposes could be increased. This would increase the water supply reliability for urban or environmental users provided they could obtain the needed water rights to bank the water. The direct, indirect, and cumulative effects of this alternative would vary depending on which user received the majority allocation. However, this alternative would not achieve MID's objectives of providing its customers with a significant increase of dry year water supply. This alternative would not meet Reclamation's purpose and need for this project.

Reduced Recharge Basin Options After discussions with the Corps, U.S. EPA, USFWS and DFG, MID and Reclamation developed Reduced Alternative B (Proposed Action) that reduced the number of acres of swales used and the number of acres of basins created. In these various options, the number of swales could be reduced and basins could be constructed to make up for the reduction in the number of acres of swales that would be used for exchange. Options ranging from basins only (Alternative C) to use of 700 acres of swales and 200 acres of basins were evaluated. Options with a heavy emphasis on basins (i.e., more than 350 acres of basins) were eliminated by Reclamation and the Corps because of environmental, logistic and cost considerations.

Section 3 Affected Environment and Environmental Consequences

This section describes the existing proposed action area environment and the potential direct, indirect and cumulative impacts to the following resources resulting from the alternatives under consideration.

- Aesthetics
- Agriculture
- Air Quality
- Biological Resources
- Cultural Resources
- Environmental Justice
- Geology, Soils, Seismicity, and Erosion
- Global Climate
- Growth Inducement
- Hazards, Public Health, and Safety
- Indian Trust Assets (ITA)
- Land Use
- Noise
- Public Services and Utilities
- Socioeconomics
- Traffic and Circulation
- Water Resources
- Water Supply
- Wetlands

3.1 Aesthetics

This section describes the potential direct, indirect and cumulative impacts to visual resources in the vicinity of Madera Ranch.

Baseline conditions in the Madera Ranch vicinity were determined by studying photographs, conducting drive-through reconnaissance, conducting research, and discussing the nature of the existing facilities with MID and Madera Ranch staff. The aesthetic effects of the alternatives were determined by assessing the visual resource changes that could result and predicting how viewers would respond to those changes.

Numerous federal agencies and organizations have developed visual assessment methodologies to standardize the quality and accuracy of visual analyses. The approach used for this visual assessment is adapted from the Federal Highway Administration's visual effects assessment system (Federal Highway Administration 1983), which is widely accepted for general visual analysis.

The visual effects assessment process involves identifying:

- relevant policies and concerns for protection of visual resources;
- visual resources (i.e., visual character and quality) of the region, the immediate vicinity of the project, and the project site;
- important viewing locations and the general visibility of the project site using descriptions and photographs;
- viewer groups and their sensitivity; and
- potential effects, mitigation of effects, and other recommendations.

The analysis of effects on aesthetics includes a qualitative assessment of the effects that construction and operation of the alternatives would have on the area's visual character and quality. A survey was conducted of the Madera Ranch site and surrounding roadways to characterize existing conditions and to identify areas sensitive to visual changes. In addition, the County's General Plan (Madera County 1995a, 1996b) was analyzed for policies or direction related to aesthetics and to determine whether there are any designated scenic roadways, vistas, or areas.

Roadways with substantial traffic in the area, specifically Avenue 7, Avenue 12, and Road 21, were considered visually sensitive, as the highest number of viewers would use these routes. Although the area contains scattered rural residential development, no residences were identified as being in direct proximity of any alternatives (i.e., immediately adjacent to the Madera Ranch site and unbuffered by distance or existing agricultural operations).

3.1.1 Affected Environment

The aesthetic value of an area is a measure of its visual character and quality, combined with the viewer response to the area (Federal Highway Administration 1983). The scenic quality component can best be described as the overall impression that an individual viewer retains after driving through, walking through, or flying over an area (U.S. Bureau of Land Management 1980).

Regional Character

Madera Ranch is located in the largely agricultural western portion of Madera County, in the area known as the Valley Floor. It is bordered by Avenue 12 to the north, Avenue 7 to the south, Road 21 to the east, and agricultural lands to the west (Figure 3-1). The regional character of this area is typical of rural agricultural regions. Typical views of the region include:

- agricultural operations, such as tree, row, and field crop production;
- agricultural storage and maintenance areas;
- irrigation canals;
- rural residences;

- agricultural wells; and
- aboveground utility facilities

Vicinity Character

The vicinity of the WSEP is considered the Madera Ranch, which is typical of the region as described above but has a greater percentage of grasslands. Figure 3-1 shows the existing land uses at Madera Ranch and surrounding lands. The majority of the site is covered with grasslands that are used for grazing. Smaller portions of the site are used for agriculture, including vineyards and row crops. A farm headquarters and storage area is located near the center of the site, and two residences are on the east side of the site. Madera Ranch is generally level with little vertical relief. Views of the foreground consist of grasslands and some row crops. To the east, the Sierra Nevada may be visible in the distance, depending on weather conditions.

Sensitive Viewers

The primary viewer groups of Madera Ranch are residents and motorists. A few farmhouses are scattered throughout the vicinity, surrounded by agricultural land. Many of the residents of these farmhouses both live and work in the area; they generally make their living from the land and thus often hold their surroundings in high esteem. They typically are sensitive to visual change because of their familiarity with the view, their investment in the area (if they are homeowners or long-time residents), and their sense of ownership of the view. The view from their homes and yards represents a visual extension of their property, and changes in this view are quickly recognized and can cause the residents to have strong reactions, both positive and negative.

In addition to local residents, people traveling on Avenue 7, Avenue 12, and Road 21 are exposed to Madera Ranch. These individuals are considered to have moderately low sensitivity to changes because they are focused more on driving and are exposed to the site for only a short period of time. However, the roadways are very straight, giving roadway travelers some limited opportunities to take in the scenery around them.

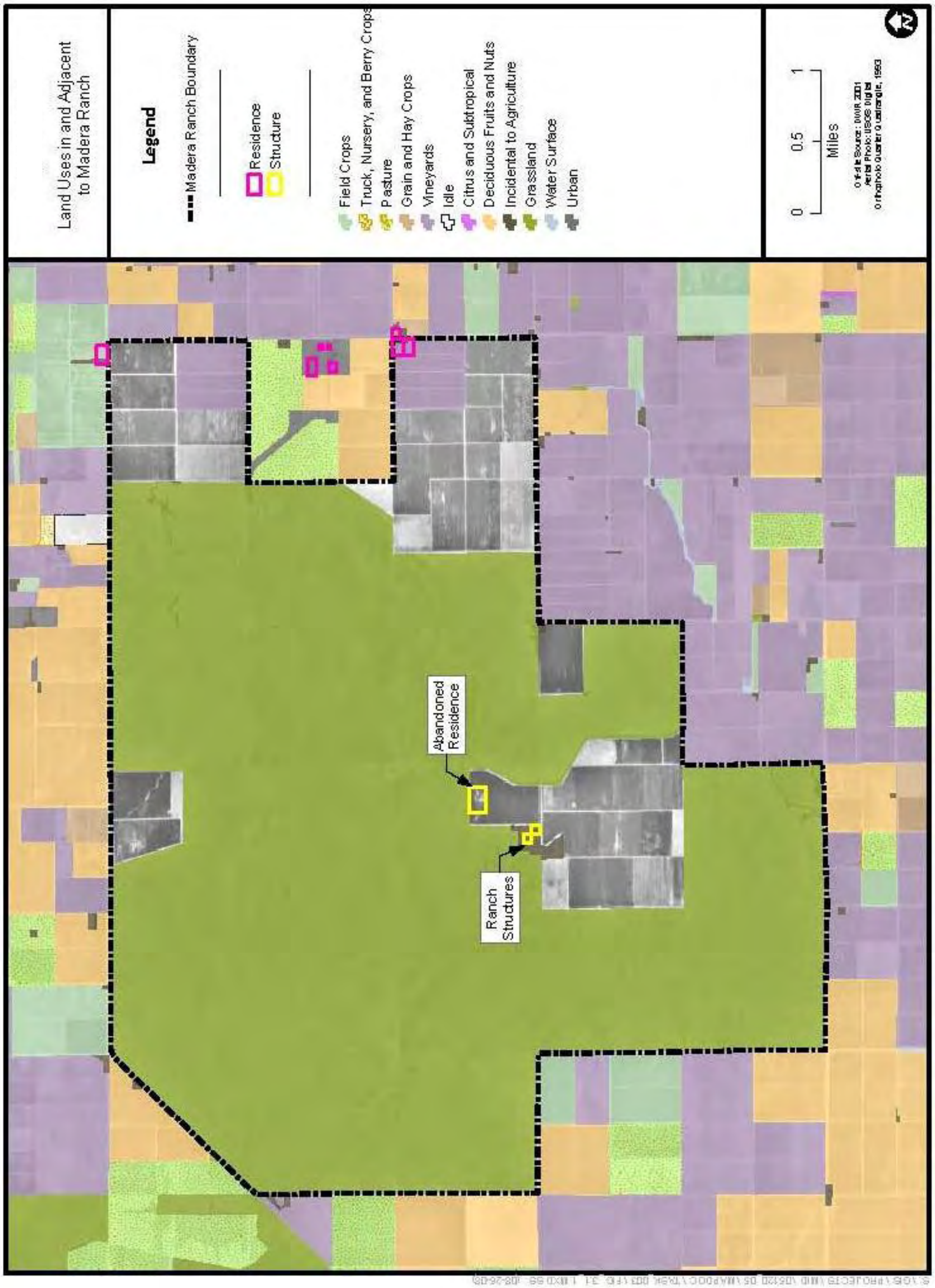

Figure 3-1 Land Uses In and Adjacent to Madera Ranch

3.1.2 Environmental Consequences

Based on a review of the *Madera County General Plan Background Report* (Madera County 1995b) and Caltrans Scenic Highway Program (California Department of Transportation 2008), no designated scenic vistas or highways are visible from or within the vicinity of the alternatives. Thus, none of the alternatives would affect scenic vistas or resources. As no night lighting is proposed, no effects associated with glare could occur.

There are no federally or state-designated scenic roadways or vistas within Madera Ranch site boundaries or its vicinity. In addition, there are no County-designated scenic roadways or vistas, and those that are eligible for such designation are located far beyond the viewshed of Madera Ranch (California Department of Transportation 2008).

Alternative A—No Action

Under the No Action Alternative, Reclamation would not approve the banking of CVP water outside MID's service area, nor would Reclamation issue an MP-620 permit (a Mid-Pacific Region specific permit for modification or alteration of Reclamation-owned facilities) to approve modifications to its distribution system. The future conditions could change to support agricultural activities. Because Madera Ranch would not be visible from population centers or major circulation routes, and because the expected features associated with the future no action conditions would appear very similar to those already present under existing conditions, the No Action Alternative would have no effect on aesthetics.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect AES-1: Temporary Degradation of Visual Character or Quality from Construction-Related Activities Construction of Alternative B action would require the use of heavy equipment and large trucks, which would cause the area to resemble a typical construction site. Construction activities involving grading, trenching, and the storage of construction equipment and materials on Madera Ranch would be visible from Avenue 7, Avenue 12, and Road 21 and adjoining properties. Construction-related activities along Cottonwood Creek, the 24.2 Canal, and Section 8 Canals also would be visible to motorists and rural residents. However, the operation of construction equipment is similar to agricultural activities that already occur in the area, including field-leveling, disking, and harvesting. In addition, construction activities would be only temporary in nature, lasting for six months for each of two construction seasons. As such, there would not be a considerable change in views, and construction-related activities would not result in a substantial adverse effect on visual character or quality.

Effect AES-2: Degradation of Visual Character or Quality from New Permanent Features Alternative B would involve:

- modification and extension of canals and drainage ditches;
- use of natural swales and construction of engineered recharge basins to recharge water; and
- installation of recovery wells, pipelines, and lift stations.

Madera Ranch would not be visible from population centers or major circulation routes. However, it would be visible from nearby residences and Avenue 7, Avenue 12, and Road 21.

Canals and drainage ditches are common visual features in the agricultural areas of Madera County and are visible from Madera Ranch. The proposed new construction and/or modifications to existing canals and drainage ditches would be consistent with the agricultural nature of the area and would be similar to other visual features already occurring in the area.

The recharge basins that would be constructed as part of Alternative B would look similar to drainage ponds that already exist in the area, which blend in visually with the surrounding environment. Environmental oriented viewer groups may find the new facilities constructed in grassland offensive because of the change in visual character due to a change in land use, however, the recharge basins would be located several miles from Avenue 12, are not expected to be visible from this road, and this group composes a minority of those using Avenue 12. Diversion of water to the swales would mimic natural processes, thus blending in with the natural environment. None of the drainages or swales to be used for recharge is visible from surrounding roads or properties. If increased numbers of migratory birds using the site were visible to motorists passing by, some of them might consider the increased migratory bird use to be a beneficial change. Under Alternative B, portions of Sections 28 and 29 periodically would be inundated, and portions of this water would be visible from Avenue 7. However, this condition would be identical to that which has existed at that location for more than 13 years. All of these recharge facilities would appear similar to flooded agricultural fields. Therefore, recharge basins and swales proposed under Alternative B would blend in with existing agricultural features in the area.

New wells, pipelines, lift stations, and utilities also would be constructed as part of Alternative B. The planned pipelines would be buried and follow alignments along existing roadways. The wells, lift stations, and utilities would be similar to features commonly found in western Madera County and the area surrounding Madera Ranch.

Because Madera Ranch would not be visible from population centers or major circulation routes, and because the planned new features would appear very similar to those present under existing conditions, Alternative B would not have an adverse aesthetic effect.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales will be used and a reduced number of ponds will be constructed. This would not result in any differences from what was described above for Alternative B relative to temporary degradation of visual character or quality from construction-related activities changes, or degradation of visual character or quality from construction of new permanent features. The effects of Reduced Alternative B would result in nearly identical effects to those that would occur under Alternative B (Effects AES-1 and AES-2), and thus, not considered adverse.

Alternative C—Water Banking Outside the MID Service Area without Swales and Alteration to Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, the visual character of the proposed engineered recharge basins would be very similar to the visual identity of the swales in Alternative B, and the effects would be nearly identical (Effects AES-1 and AES-2). As described above for these effects, the area is used for agricultural purposes, and the construction activities and resulting changes in facilities (such as canals and lift stations) would result in similar views from within the ranch and from nearby residences and Avenue 7, Avenue 12, and Road 21 compared to the existing activities and facilities on the Ranch. Pipelines would be buried and would result in no changes in aesthetics. The constructed basins proposed as part of Alternative C would be similar to flooded fields. Thus, there would be no considerable changes in aesthetics during or after construction that would result in any adverse visual effects.

Alternative D—Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water conveyance to the site occurs primarily through GF Canal and not the Section 8 Canal and other local conveyances. Thus, the visual character of the alternative would be similar to Alternative B, and the effects on aesthetics would be nearly identical (Effects AES-1 and AES-2). As described above for these effects, the area is currently used for agricultural purposes, and the construction activities and resulting changes in facilities (such as canals and lift stations) would result in similar views from within the ranch and from nearby residences and Avenue 7, Avenue 12, and Road 21 compared to the existing activities and facilities on the Ranch. Pipelines would be buried and would result in no changes in aesthetics. The constructed basins proposed as part of Alternative D would be similar to flooded fields. More water than usual would be seen in GF Canal, but this would not represent a significant change in the visual character of the area and would not represent an adverse effect. Thus, there would be no considerable changes in aesthetics during or after construction that would result in any substantial adverse visual effects.

Cumulative Effects

Because the Proposed Action and alternatives will not result in adverse effects on visual resources, no cumulative effects are anticipated.

3.2 Agriculture

This section describes the agricultural resources for the areas potentially affected by the proposed alternatives. It discusses the affected environment, relevant regulations and policies, methods of analysis, and possible effects.

3.2.1 Affected Environment

Agricultural lands make up 47% (648,300 acres) of the total Madera County land area. In 2007, the top five crops were grapes, almonds, nuts, and hulls, milk, pistachios; cattle and calves. Nuts, almonds, hulls, grapes, and pistachios (along with many other crop types in the county) represent permanent crops that cannot easily be abandoned or fallowed from year to year. Approximately 86% of the cultivated land in Madera County is in permanent crops.

The majority of the land in the Madera Ranch vicinity is used for grazing with some areas in row crop production. A small portion is planted in vineyards. Table 3-1 summarizes these land uses and lists the corresponding acreages.

Table 3-1 Summary of Current Land Use on Madera Ranch

Land Use	Acres
Vineyards	320
Grain and hay crops	2,424
Annual grassland used for grazing	10,878
Semi-agricultural & incidental to agriculture*	24
Total	13,646

* Ranching facilities and Cottonwood Creek.

Table 3-2 shows land classification acreages on Madera Ranch and in the entire county. Madera Ranch represents approximately 1.8% of the county's total Important Farmland (California Department of Conservation 2006b).

Table 3-2 Acreages of Important Farmland

Important Farmland Category	Madera Ranch	County
Prime Farmland	1,085	97,489
Farmland of Statewide Importance	491	85,135
Unique Farmland	1,017	163,973
Farmland of Local Importance	151	17,415
Grazing Land	10,978	399,499
Total	**13,722**	**765,159**

Note: Acreages reported by various agencies differ slightly from those reported by the Madera County Assessor's Office.

Source: California Department of Conservation 2006b (2004–2006 data).

Agricultural land can be protected under the Williamson Act within designated agricultural preserves[1]. The entire site at Madera Ranch is under Williamson Act contracts. These Williamson Act contracts will remain in effect indefinitely because no notice of nonrenewal or application for cancellation has been submitted (Upton pers. comm.). Portions of the properties outside of Madera Ranch along the Section 8 and 24.2 Canals are also part of the farmland security zone.

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[1] An *agricultural preserve* is the –area within which a city or county will enter into Williamson Act contracts with landowners. The boundary [of the agricultural preserve] is designated by resolution of the board or city council having jurisdiction. Agricultural preserves must generally be at least 100 acres in size" (California Department of Conservation 2007).

Potential effects of an action on agricultural resources fall into two categories: indirect effects on the ability of farmland to support various levels of crop or livestock production, and the direct removal of land from agricultural use. Direct effects are caused by the action and occur at the same time and place. Indirect effects are caused by the action and are later in time or farther removed in distance but are still reasonably foreseeable. The effects on agricultural resources are assessed based on direct disturbances related to construction and changes in land use resulting from new facilities, and indirect changes related to changes in water supplies for agricultural uses.

The ability of farmland to support various levels of crop or livestock production is referred to as *farmland quality*. The factors that affect farmland quality include the physical and chemical characteristics of a site's soils and the topography, climate, and quality and availability of irrigation water.

Under its Farmland Mapping and Monitoring Program (FMMP), the California Department of Conservation prepares maps of Important Farmlands, as described below (California Department of Conservation 2004, 2006a). Important Farmland maps are prepared periodically for most of the state's agricultural areas based on information from Natural Resources Conservation Services (NRCS) soil survey maps and land inventory and monitoring criteria developed by the NRCS. These criteria generally are expressed as definitions that characterize the land's suitability for agricultural production, physical and chemical characteristics of the soil, and actual land use. Important Farmland maps generally are updated every 2 years.

The Important Farmland mapping system uses eight mapping categories—five categories relating to agricultural lands and three categories associated with nonagricultural lands. The five agricultural mapping categories are summarized below.

- *Prime Farmland* includes lands with the combination of physical and chemical features best able to sustain long-term production of agricultural crops. The land must be supported by a developed irrigation water supply that is dependable and of adequate quality during the growing season. It also must have been used for the production of irrigated crops at some time during the 4 years before the mapping data were collected.
- *Farmland of Statewide Importance* refers to lands with agricultural characteristics, irrigation water supplies, and physical characteristics similar to prime farmland but with minor shortcomings, such as steeper slopes or less ability to hold and store moisture.
- *Unique Farmland* is lands with lesser quality soils used for the production of California's leading agricultural cash crops. These lands usually are irrigated but may be nonirrigated orchards or vineyards as found in some of the state's climatic zones.
- *Farmland of Local Importance* refers to lands of importance to the local agricultural economy, as determined by each county's board of supervisors and a local advisory committee. The county includes in its definition of farmland of local importance those lands that are presently under cultivation for small grain crops but that are not irrigated. The definition also includes lands that are currently in irrigated pasture but have the potential to be cultivated for row/field crop use.

- *Grazing Land* is land on which the existing vegetation is suited to the grazing of livestock.

Figure 3-2 shows the FMMP categories present on Madera Ranch.

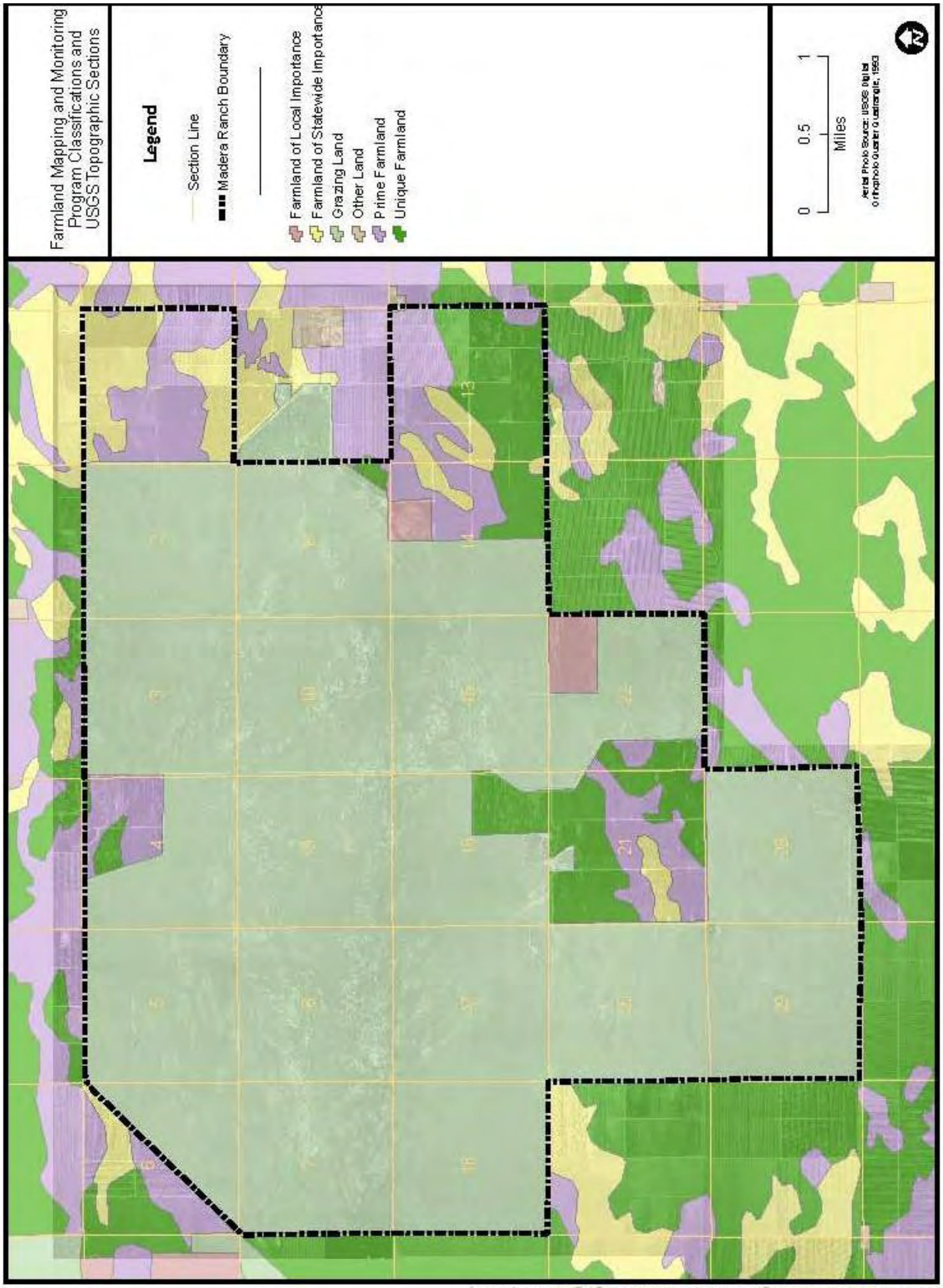


Figure 3-2 Farmland Mapping and Monitoring Classifications and USGS Topographic Classifications

3.2.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative, Reclamation would not approve the banking of CVP water outside MID's service area, nor would Reclamation issue an MP-620 permit, a Mid-Pacific Region specific permit for modifications to its distribution system. However, the future conditions would likely change. If MID sells the property to agricultural users, additional property on Madera Ranch would go into agricultural production. Potential conflicts with Williamson Act contracts, loss of agricultural land designated as important farmland, or conflict with local zoning designations would need to be evaluated by MID or the County under CEQA, depending on the discretionary permits needed. Until MID sells the property, it would continue in its current use of grazing.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect AG-1: Alteration of Madera Ranch Agricultural Operations Alternative B would not change the pattern of agricultural operations at the site. Furthermore, MID's water conveyance facilities allow delivery of surface water to the property without any physical changes. Proposed canal expansions would allow an increase in water delivery to the property that would be banked on site for later recovery and use in MID's current service area. It is not expected that the banked water would be recovered for use on Madera Ranch. Rather, the water would be transferred back into MID's service area for use. Thus, there would be no effect on agricultural areas associated with water banking operations at Madera Ranch.

Effect AG-2: Conflict with Williamson Act Contracts According to the Williamson Act (Government Code sec. 51202[e]), a compatible use is any use determined by the county or city administering the agricultural preserve to be compatible with the agricultural, recreational, or open-space use of land within the preserve and subject to contract. The County Planning Department previously has determined that development of a groundwater bank on the Madera Ranch site would not conflict with the AE designation (Merchen pers. comm.). According to the County, the following activities are considered compatible uses: “the erection, construction, or maintenance of a water facility” (Madera County Rules and Procedures for Agricultural Preserves, California Government Code 51238). In addition, as discussed above, the changes resulting from Alternative B would be compatible with existing agricultural land use and zoning designations. Additionally, water banked and recovered at Madera Ranch would be used by MID, which provides water primarily for agricultural uses. One of the project purposes is to improve the reliability of the water supply. It is expected that will help ensure that any Williamson Act properties to which this water is applied can be maintained in their current land use. For these reasons, Alternative B would not conflict with any Williamson Act contracts and would have no effect on Williamson Act compatibility.

Effect AG-3: Loss of Agricultural Land Designated as Prime Farmland or Farmland of Statewide Importance Implementation of the Alternative B would result in the direct loss of approximately 27 acres of prime farmland. Approximately 13 acres of farmland of statewide importance would be lost at Madera Ranch, and an additional 4.6 acres of farmland of statewide importance would be lost as a result of the 24.2 Canal extension (for a total of 17.3 acres). This represents a loss of approximately 2.8% of the prime farmland and farmland of statewide importance at Madera Ranch. However, the majority of the changes associated with Alternative B would occur on land classified by the FMMP as grazing land. Figure 3-3 shows the locations of the facilities that would result in the direct conversion of farmland, and Table 3-3 shows the acreages of farmland that would be converted. Alternative B would not result in conversion of farmland outside Madera Ranch; rather it is likely that the WSEP would support existing prime farmland and farmland of statewide importance because the increased water supply reliability would maintain favorable conditions for farmers to continue farming operations on those lands.

Although the loss of prime farmland and farmland of statewide importance at Madera Ranch is relatively small, and a primary objective of the WSEP is to help preserve agricultural land use through the provision of reliable and affordable water supplies, this effect is considered adverse because it would convert prime farmland or farmland of statewide importance to a nonagricultural land use. Conservation easements on agricultural land would be established (Environmental Commitment AG-1) that would reduce the intensity of this effect.

Effect AG-4: Conflict with Local Zoning Designations Madera Ranch is located within the AE general plan land use designation and is zoned for agricultural use, meaning that the future land use must be compatible with agricultural uses. The County Planning Department previously has determined that development of groundwater storage on the Madera Ranch site would not conflict with the AE designation (Merchen pers. comm.).

In addition, only a small portion of the site, approximately 1,101 acres or 8% of the site, would be used for water banking facilities under Alternative B. Agriculture would continue on Madera Ranch except where recharge basins would be established and permanent, unburied facilities would be located. Land removed from agricultural production would continue to support agricultural practices and be consistent with the Agricultural Exclusive (AE) designation. Grazing would continue on the majority of the ranch along with row crop production. MID does not propose to establish grassland conservation easements on prime farmland, unique farmland, or farmland of statewide importance. However, other areas of the ranch may continue to be used for grazing per grassland conservation easements.

Modification and extension of existing ditches and canals would cause only temporary disruption and would result in changes that also would be consistent with continued agricultural production on the extensive agricultural areas of the site as well as on adjoining properties. Furthermore, implementation of Alternative B would enhance water reliability and flexibility and help to maintain water costs at levels that are affordable to farmers. Because Alternative B would not conflict with local zoning designations, there would be no effect.

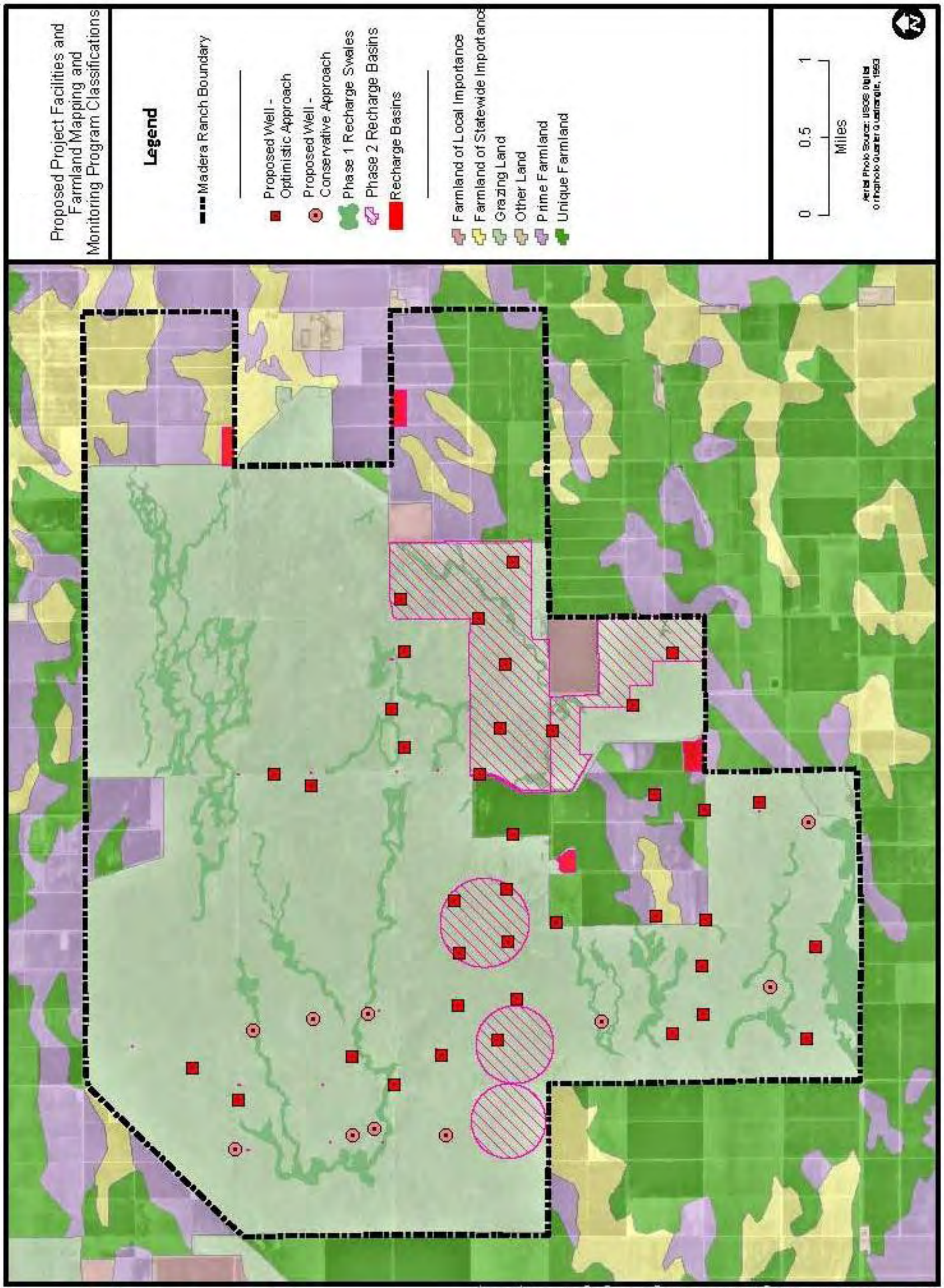


Figure 3-3 Proposed Project Facilities and Farmland and Monitoring Program Classifications

BDCP1738.

Table 3-3 Areas of Farmland Affected by the Proposed Alternatives

Madera Ranch		Alternative B				Reduced Alternative B				Alternative C				Alternative D			
		Phase 1	Phase 2*	Total	Percent	Phase 1	Phase 2*	Total	Percent	Phase 1	Phase 2**	Total	Percent	Phase 1	Phase 2*	Total	Percent
Prime Farmland	1,085	23.6	2.9	26.5	2.4	23.6	2.9	26.5	2.4	26.5	n/a	26.5	2.4	23.6	2.9	26.5	2.4
Farmland of Statewide Importance	491	17.3	0.08	17.38	3.5	17.3	0.08	17.38	3.5	17.38	n/a	17.38	3.5	0	0.08	0.08	<0.1
Unique Farmland	1,017	11.1	4.6	15.7	1.5	11.1	4.6	15.7	1.5	15.7	n/a	15.7	1.5	11.1	4.6	15.7	1.5
Farmland of Local Importance	151	0	4.04	4.04	2.7	0	4.04	4.04	2.7	4.04	n/a	4.04	2.7	0	4.04	4.04	2.7
Grazing Land	10,978	18.0	1,020*	1038	9.5	0	501	501	9.6	1,038	n/a	1038	9.5	18.0	1,020*	1038	9.5
Total	**13,722**			**1,101.62**				**564.62**			**1,101.62**				**1,084.32**		

*The potential impacts of Alternative B, Reduced Alternative B and Alternative D, Phase 2 to grazing land represent a maximum value. These impacts, which would be associated with construction of engineered recharge basins, would not occur if the use of natural swales for recharge under Phase 1 meets the proposed objectives.

**Under Alternative B, all recharge facilities are constructed during Phase 1.

Source: California Department of Conservation 2006b (2004–2006 data).

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales will be used and a reduced number of ponds will be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. Similar to what was described for Alternative B above for Effects AG-1, AG-2, AG-3, and AG-4, Reduced Alternative B would result in conversion of approximately 27 acres of prime farmland and 17 acres of farmland of statewide importance, but would not change agricultural operations on Madera Ranch or elsewhere and would not result in conflicts with Williamson Act contracts or County zoning regulations. Thus, effects on agricultural resources are considered equivalent to those that would occur under Alternative B and are considered adverse only because of conversion of prime farmland or farmland of statewide importance to a nonagricultural land use (as described in Effect AG-3). Conservation easements on agricultural land would be established (Environmental Commitment AG-1) that would reduce the intensity of this effect.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. However, the expected footprint of recharge basins under Alternative C would be identical to Alternative B and would result in similar effects. Similar to what was described for Alternative B above for Effects AG-1, AG-2, AG-3, and AG-4, Alternative C would result in conversion of approximately 27 acres of prime farmland and 17 acres of farmland of statewide importance, but would not change agricultural operations on Madera Ranch or elsewhere and would not result in conflicts with Williamson Act contracts or County zoning regulations. Thus, effects on agricultural resources are considered equivalent to those that would occur under Alternative B and are considered adverse only because of conversion of prime farmland or farmland of statewide importance to a nonagricultural land use (as described in Effect AG-3). Conservation easements on agricultural land would be established (Environmental Commitment AG-1) that would reduce the intensity of this effect.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B. The expected footprint of recharge basins under Alternative D would be similar to Alternative B and would result in equivalent effects relative to changes in agricultural land use, consistency with zoning and the general plan, and effects on lands included in Williamson Act contracts (Effects AG-1, AG-2, AG-3, and AG-4). However, under Alternative D, the loss of farmland of statewide importance would be less than that described for Alternative B. (Less than 1/10 of an acre under Alternative D compared to approximately 17 acres converted under Alternative B). Thus, effects on agricultural resources are considered similar in scope to those that would occur under Alternative B and are considered adverse only because of conversion of prime farmland or farmland of statewide importance to a nonagricultural land use (as described in Effect AG-3). Conservation easements on agricultural land would be established (Environmental Commitment AG-1) that would reduce the intensity of this effect.

Cumulative Effects

Other projects, combined with the WSEP, have the potential to result in a cumulative effect on agriculture in Madera County. Specifically, development projects could result in permanent conversion of agricultural land to urbanized areas, and reductions in county-wide agricultural production would continue as water becomes more expensive and limited. However, the WSEP's contribution is not considerable. Agriculture would continue on Madera Ranch except where permanent, unburied facilities are located. MID does not propose to establish grassland conservation easements on prime farmland, unique farmland, or farmland of statewide importance. However, other areas of the ranch may continue to be used for grazing per grassland conservation easements. MID is mitigating agricultural conservation easements at a 2:1 ratio to fully compensate for the loss of prime farmland, unique farmland, and farmland of statewide importance associated with all of the alternatives. Furthermore, the alternatives would help maintain the viability of agriculture in Madera County. Thus, it is not anticipated that the alternatives would contribute to cumulative impacts on agriculture.

3.3 Air Quality

This section describes the existing air quality conditions in the areas potentially affected by the Proposed Action and alternatives. It discusses the affected environment, relevant regulations and policies, methods of analysis, possible effects, and mitigation efforts.

3.3.1 Affected Environment

Ambient air quality is affected by the climate, topography, and the type and amount of pollutants emitted. The location of the WSEP, Madera Ranch, is subject to a combination of topographical and climatic factors that result in high potential for regional and local accumulation of pollutants.

Climate and Topography

Madera Ranch is located in the San Joaquin Valley Air Basin (SJVAB). The mountain ranges bordering the air basin near the site (the Coast Ranges to the west and Sierra Nevada to the east) influence wind directions and speeds and atmospheric inversion layers in the San Joaquin Valley. These mountain ranges channel winds through the valley, affecting both the climate and dispersion of air pollutants.

Because of the mountain ranges bordering the air basin, temperature inversions occur frequently in the valley. Inversions occur when the upper air is warmer than the air beneath it, thereby trapping pollutant emissions near the earth's surface and not allowing them to disperse upward. Inversions occur frequently throughout the year in the San Joaquin Valley, although they are more prevalent and of a greater magnitude in the late summer and fall months.

Ambient Air Quality Standards and Existing Air Quality Conditions

The Proposed Action area lies within the SJVAB under the jurisdiction of the San Joaquin Valley Air Pollution Control District (SJVAPCD). The pollutants of greatest concern in the San

Joaquin Valley are carbon monoxide (CO), ozone (O_3), O_3 precursors such as volatile organic compounds (VOC), inhalable particulate matter between 2.5 and 10 microns in diameter (PM_{10}) and particulate matter less than 2.5 microns in diameter ($PM_{2.5}$).

The SJVAB has reached Federal and State attainment status for CO, nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). Federal attainment status has been reached for PM_{10} but is in non-attainment for O_3, $PM_{2.5}$, and VOC. There are no established standards for oxides of nitrogen (NO_x); however, NO_x does contribute to NO_2 standards (San Joaquin Valley Air Pollution Control District 2011).

The Federal CAA, enacted in 1963 and amended several times thereafter establishes the framework for modern air pollution control. The EPA has established National Ambient Air Quality Standards (NAAQS) (Table 3-4) for criteria pollutants. Criteria pollutants include CO, NO_2, SO_2, O_3, PM_{10}, and $PM_{2.5}$, and lead. Most standards have been set to protect public health. For some pollutants, standards have been based on other values (such as protection of crops, protection of materials, or avoidance of nuisance conditions).

Table 3-4 Applicable State and Federal Ambient Air Quality Standards

Pollutant	**Averaging Time**	**California Standards**		**National Standards**	
		Concentration	**Attainment Status**	**Concentration**	**Attainment Status**
O_3	8 Hour	0.070 ppm (137 µg/m^3)	**Nonattainment**	0.075 ppm (147 µg/m^3)	**Nonattainment**
	1 Hour	0.09 ppm (180 µg/m^3)	**Nonattainment**	--	--
CO	8 Hour	9 ppm (10 mg/m^3)	Attainment	9.0 ppm (10 mg/m^3)	Attainment
	1 Hour	20 ppm (23 mg/m^3)	Unclassified	35 ppm (40 mg/m^3)	Unclassified
NO_2	Annual arithmetic mean	0.030 ppm (56 µg/m^3)	Attainment	0.053 ppm (100 µg/m^3)	Attainment
	1 Hour	0.18 ppm (338 µg/m^3)	Attainment	--	--
SO_2	Annual average	--	--	0.03 ppm (80 µg/m^3)	Attainment
	24 Hour	0.04 ppm (105 µg/m^3)	Attainment	0.14 ppm (365 µg/m^3)	Attainment
	1 Hour	0.25 ppm (655 µg/m^3)	Attainment	--	--
PM_{10}	Annual arithmetic mean	20 µg/m^3	**Nonattainment**	--	--
	24 Hour	50 µg/m^3	**Nonattainment**	150 µg/m^3	Attainment
$PM_{2.5}$	Annual Arithmetic mean	12 µg/m^3	**Nonattainment**	15 µg/m^3	**Nonattainment**
	24 Hour	--	--	35 µg/m^3	Attainment
Lead	30 day average	1.5 µg/m^3	Attainment	--	--
	Rolling-3 month average	--	--	0.15 µg/m^3	Unclassified

Source: California Air Resources Board 2011; San Joaquin Valley Air Pollution Control District 2011; 40 CFR 93.153
ppm = parts per million
mg/m^3 = milligram per cubic meter
µg/m^3 = microgram per cubic meter
-- = No standard established

Federal Conformity Requirements

The CAA and amendments require that all federally funded projects come from a plan or program that conforms to the appropriate State Implementation Plan (SIP). Federal actions are subject to either the transportation conformity rule (40 CFR 51[T]), which applies to federal highway or transit projects, or the general conformity rule. Because the Proposed Action is not a federal highway or transit project, it is subject to the General Conformity Rule.

The purpose of the general conformity rule is to ensure that federal projects conform to applicable SIPs so that they do not interfere with strategies employed to attain the NAAQS. The rule applies to federal projects in areas designated as nonattainment areas for any of the six criteria pollutants and in some areas designated as maintenance areas.

Madera Ranch is located in a federal extreme nonattainment area for O_3 and nonattainment area for $PM_{2.5}$. Consequently, to fulfill general conformity requirements, an analysis must be undertaken to identify whether the Proposed Action's total emissions of O_3, and $PM_{2.5}$:

- are below the appropriate *de minimis* levels, and
- are regionally insignificant (total emissions are less than 10% of the area's total emissions inventory for that pollutant).

3.3.2 Environmental Consequences

The Proposed Action would generate construction-related emissions and operational emissions. The approach used to evaluate construction and operational effects is described below.

Construction Effects Assessment Methods

Construction of the Proposed Action would generate pollutant emissions from a variety of emission sources and activities. All phases of project construction – project mobilization, site preparation, site clearing and grubbing, and construction – would generate air emissions. The primary pollutant-generating activities associated with these phases include:

- exhaust emissions from off-road construction vehicles and equipment;
- exhaust emissions from vehicles used to deliver supplies to the project site or to haul materials from the site;
- exhaust emissions from worker commute trips;
- fugitive dust from grading; and
- fugitive dust from equipment operating on exposed earth and from the handling of sand, gravel, aggregate, and associated construction materials.

Construction of the Proposed Action would generate emissions of Reactive Organic Gases (ROG), NO_x, CO, sulfur oxides (SO_x), and PM_{10}. Construction-related emissions also would include fugitive PM_{10} dust from site grading and exhaust emissions resulting from worker commute trips and off-road construction equipment. Emissions from off-road construction equipment are estimated based on the California Air Resources Boards's off-road model (California Air Resources Board 2007). Fugitive dust emission factors are based on research done by the Midwest Research Institute for the South Coast Air Quality Management District (Midwest Research Institute 1996).

Construction equipment for the Proposed Action during Phase 1 would most likely include:

- 18 heavy diesel-powered scrapers (40- to 60-yard capacity);
- five 500- hp diesel-powered skip loaders;
- 30 heavy-duty, off-road-type, diesel-powered, bottom dump trucks (60-yard capacity);
- five large, diesel-powered, crawler-type tractors;
- five diesel-powered motor graders;
- three diesel-powered, large-capacity water tankers;
- three diesel-powered trackhoes;
- four well drill rigs (most likely diesel-powered) and support equipment in the form of semi-trailer trucks;
- five rubber-tired, diesel-powered backhoes; and
- support equipment, such as maintenance rigs.

In addition to the equipment listed above, construction would require up to 3,500 loads of concrete in diesel-powered transit mixers, 50 diesel semi-trailer loads of well casing, 15 diesel semi-trailer loads of pumping equipment, and 20 diesel semi-trailer loads of other equipment.

All but the off-road bottom dumps and drill rigs would be brought in on semi-trailer trucks. Some of the haul rigs would be up to 13-axle rigs to carry the weight of the scrapers. Except for some maintenance rigs, all would be stored on site during the construction period.
Several daily trips would be made to pick up supervising staff, surveyors, and inspectors. In addition, equipment operators would be traveling to and from the site daily. During construction, fuels and lubricants would be transported on a daily basis.

During Phase 2, a similar but lesser amount of heavy equipment would be mobilized and used on the Madera Ranch to construct the additional ponds in Sections 16, 17, and 18.

The grading phase of construction would use the largest amount of heavy-duty construction equipment and would be the primary source of emissions during construction. Under the Proposed Action, the construction site would be mass graded, with a first grading phase of about 540,000 cy and a possible second phase grading of about eight million cy; grading activities would occur over several years. Based on the description of the Proposed Action, the grading activity is estimated to involve four bulldozers, eight rubber-tired scrapers, two graders, and as many as three water trucks used for controlling dust and conveying compaction water. The actual number of water-spreading pieces of equipment would depend on how much compaction water could be directly applied through hoses and pipes. In addition to the emissions associated with operation of construction equipment, worker commute trips would contribute a small amount of emissions.

The information shown in Table 3-5 was used to estimate construction-related emissions during peak construction days.

Table 3-5 Amount and Types of Heavy Equipment to Be Used for Mass Grading during Peak Construction Activities

Equipment Type	Alternatives B, Reduced Alternative B and C	Alternative D
Bulldozers	4	2
Rubber-tiered scrapers	8	6
Motor grader	2	1
Water trucks	3	2

The estimated size and number of engines for wells and lift station pumps used worst-case engine hp requirements to ensure that all potentially adverse effects are disclosed. However, actual or average emissions may be substantially lower.

Alternative A—No Action

Under the No Action Alternative, Reclamation would not approve the banking of CVP water outside MID's service area, nor would Reclamation approve of modifications to its distribution system. The No Action Alternative would have no adverse effects on air quality. However, the future conditions would change to support agricultural activities or water banking activities.

Under the No Action Alternative, the changes to air quality could vary. MID likely would sell the property to agricultural users and additional air quality effects could occur because additional lands would go into agricultural production; however, the amount and type of air quality effects would depend on the future agricultural practices. The SJVAB, which includes Madera County, would continue to be in severe nonattainment for O_3 and for $PM_{2.5}$. The future conditions would be evaluated by MID or the County under CEQA depending on the discretionary permits needed. If MID sells the property to others interested in water banking, the effects would be similar to those described under the Proposed Action. The types of facilities and number of wells may vary depending on the quantity of water proposed to be banked.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect AQ-1: Generation of Construction Emissions in Excess of Federal de Minimis Threshold Levels Grading associated with Alternative B, including balanced cut and fill, would require the movement of approximately 8.8 million cy of soil. Grading would be balanced on site in order to eliminate the need to haul additional fill material to the site or to haul excess material off site. These preliminary grading activities are expected to involve multiple pieces of heavy construction equipment, listed in Table 3-6.

Construction of Alternative B would generate short-term fugitive PM_{10} dust as a result of activities that disturb the soil, such as grading and excavation, and ROG, NO_x, CO, PM_{10}, and $PM_{2.5}$ from exhaust. Estimated annual air pollutant emissions during on-site grading are shown in Table 3-6. Estimates are based on a fugitive dust emission factor developed for construction activities in California. Actual fugitive dust emissions may differ slightly based on variations in soil type, wind, and soil moisture.

Table 3-6 Maximum Yearly Construction Emissions for Alternative B (tons per year)

Emission Source	ROG	NO_x	PM_{10}	$PM_{2.5}$
Alternative B (on-site heavy equipment including fugitive dust and worker trips)				
Phase 1	6.5	28.3	19.7	4.8
Phase 2	3.5	28.4	19.9	4.9
Worker Trips—Fresno	0.6	0.5	0.4	0.1
Worker Trips—Madera	0.1	0.1	0.0	0.0
Worker Trips—Chowchilla/Firebaugh	0.0	0.0	0.0	0.0
Haul Trucks	0.5	7.1	0.3	0.3
Total	**11.2**	**64.4**	**40.3**	**10.1**
Federal *de minimis* Threshold Levels	10	10	100	100
Regionally Significant Threshold (10% threshold)	13,870	23,881.95	10,902.55	10,902.55

Construction activities also would generate fugitive dust and exhaust PM_{10}. Sources of fugitive dust and PM_{10} include:

- excavating soils and sediment,
- loading the excavated material onto trucks,
- tracking dirt onto paved surfaces,
- generating truck exhaust, and
- releasing dust to blow in the wind.

As shown in Table 3-6, Alternative B would result in a net increase in ROG, NO_x, PM_{10}, and $PM_{2.5}$ emissions. The increases ROG and NO_x emissions are in excess of the federal *de minimis* threshold levels. Environmental Commitments AQ 1: Implement SJVAPCD Regulation VIII Control Measures, and AQ-2: Reduce Emissions Associated with Idling Equipment, would reduce these emissions, but not to below federal *de minimis* levels. Consequently, implementation of Alternative B is not found to be a conforming project, and there would be an adverse effect.

Effect AQ-2: Generation of Operational Emissions in Excess of Federal de Minimis Threshold Levels Operation of Alternative B would require pumping at wells and lift stations to deliver water to users. For the purpose of this analysis, MID has conservatively assumed that all new pump locations could be propane-powered. Propane-fueled IC engines that exceed 50 hp would require a permit from the SJVAPCD. These new engines would be subject to SJVAPCD rules and regulations and would have to meet best available control technology (BACT) standards. Alternative B includes an engine specification requiring the purchase and use of IC engines with catalytic controls. In addition, all engines greater than 50 hp would need to meet the emission limitations published in the SJVAPCD BACT clearinghouse. Therefore, the emission estimates for operations that are compared to the threshold are the controlled engine emission estimates. Emissions above this level would not be expected to occur because they would not meet the engine specifications set by MID nor would they comply with the applicable BACT guideline. Because the electric pumps at existing wellhead locations are not expected to contribute any operational emissions, they are not addressed in this analysis, which focuses instead on the potential emissions associated with cycling and operation of the propane-fueled IC (catalytic-controlled) engines.

The engines could be used up to 24 hours per day and up to a total operating time of 2,880 hours per year. The emission estimate uses the worst-case scenario of 102 engines with a combined total of 7,385 hp. As shown in Table 3-7, normal operation of the propane-fueled engines with emission control devices is not expected to generate emissions in excess of the federal *de minimis* thresholds. Thus, given the commitment to use engines with catalytic control and the SJVAPCD BACT requirement for engines over 50 hp, the controlled emissions are less than the threshold. Therefore, the potential effect is not considered adverse.

Table 3-7 Alternative B–Related Emissions from Operations (tons per year)

	VOC	NO_x	PM_{10}
Controlled emissions from IC engines at wells and lifts/stations	3.51	3.51	14.05
Federal *de minimis* Threshold Levels	10	10	100
Regionally Significant Threshold (10% threshold)	13,870	23,881.95	10,902.55

Notes:
Estimate assumes a combined total of 7,385 hp.
Estimate assumes engine operating time of 2,880 hours per year.
Emission factors based on SJVAPCD BACT Guideline 3.3.12 (San Joaquin Valley Air Pollution Control District 2002).

This emission estimate is based on a worst-case scenario of all engines operating on propane fuel and pessimistic assumptions for the maximum number of engines required. In the event that a combination of propane- and electric-powered engines is used or fewer engines are required, the emissions would be reduced.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales will be used and a reduced number of basins will be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. However, the construction activities and operational needs under Reduced Alternative B would be similar to Alternative B and would result in equivalent effects on air quality (Effects AQ-1 and AQ-2). Thus, effects on air quality are considered equivalent to those which would occur under Alternative B and are considered adverse for construction activities. Implementation of Environmental Commitment AQ-1: Implement SJVAPCD Regulation VIII Control Measures, and AQ-2: Reduce Emissions Associated with Idling Equipment, would reduce the severity of this effect.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. However, the construction activities and operational needs under Alternative C would be similar to Alternative B and would result in equivalent effects on air quality (Effects AQ-1 and AQ-2). Thus, effects on air quality are considered equivalent to those which would occur under Alternative B and are considered adverse for construction activities. Implementation of Environmental Commitment AQ-1: Implement SJVAPCD Regulation VIII Control Measures, and AQ-2: Reduce Emissions Associated with Idling Equipment, would reduce the severity of this effect.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is nearly identical in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. The off-ranch portions of the GF Canal would require the movement of 15,000 cy of soil, and operation of the following equipment is anticipated, in addition to the equipment in Table 3-3:

- 18 heavy diesel-powered scrapers (40- to 60-yard capacity);
- five 500-hp diesel-powered skip loaders;
- 30 heavy-duty, off-road-type, diesel-powered, bottom dump trucks (60-yard capacity);
- five large, diesel-powered, crawler-type tractors;
- five diesel-powered motor graders;
- two diesel-powered, large-capacity water tankers;
- three diesel-powered trackhoes;
- four well drill rigs (most likely diesel-powered) and support equipment in the form of semi-trailer trucks;
- five rubber-tired, diesel-powered backhoes; and
- support equipment, such as maintenance rigs.

Construction activities associated with Alternative D are shown in Table 3-8.

Table 3-8 Maximum Yearly Construction Emissions for Alternative D (tons per year)

Emission Source	ROG	NO_x	PM_{10}	$PM_{2.5}$
Alternative B (on-site heavy equipment including fugitive dust and worker trips)				
Phase 1	8.4	36.6	20.2	5.2
Phase 2	3.5	28.4	19.9	4.9
Worker Trips—Fresno	0.6	0.5	0.4	0.1
Worker Trips—Madera	0.1	0.1	0.0	0.0
Worker Trips—Chowchilla/Firebaugh	0.0	0.0	0.0	0.0
Haul Trucks	0.5	7.1	0.3	0.3
Total	**13.1**	**72.7**	**40.8**	**10.5**
Federal *de minimis* Threshold Levels	10	10	100	100
Regionally Significant Threshold (10% threshold)	13,870	23,881.95	10,902.55	10,902.55

As shown in Table 3-8, Alternative D would result in a net increase in ROG, NO_x, PM_{10}, and $PM_{2.5}$ emissions. The increase in NO_x emissions is in excess of the federal *de minimis* threshold levels. Implementation of Environmental Commitments AQ 1: Implement SJVAPCD VIII Control Measures, and AQ-2: Reduce Emissions Associated with Idling Equipment, would reduce the intensity of this effect, but not to below federal *de minimis* levels. Consequently, implementation of Alternative D is not found to be a conforming project, and there would be an adverse effect.

Operational needs that effect air quality under Alternative D would be similar to Alternatives C and B and would result in equivalent effects on air quality (Effect AQ-2). Therefore, the potential effect is not considered adverse.

Cumulative Effects

Effect AQ-3: Result in a Cumulative Net Increase of Any Criteria Pollutant for Which the Region Is in Nonattainment under an Applicable Federal or State Ambient Air Quality Standard (Including Releasing Emissions That Exceed Quantitative Thresholds for O_3 Precursors) The Madera Ranch site is located in the SJVAB, where air quality conditions are regulated by SJVAPCD. Although the application of the Guide for Assessing and Mitigating Air Quality Impacts (GAMAQI) control measures to this effect would minimize adverse effects, the SJVAPCD assumes air emissions to be cumulatively adverse if, with Environmental Commitments, there remains any increase in a pollutant for which the SJVAB is classified as a nonattainment area (69 FR 20550). The SJVAB is in nonattainment for O_3 and PM_{10}.

The SJVAPCD has not established threshold criteria for construction emissions. However, because construction would result in emissions of O_3 precursors (ROG and NO_x) and PM_{10}, and could result in the cumulative net increase in these pollutants, effects of construction emissions could be adverse. Because construction would not be long-term, construction of the alternatives would not contribute to the cumulative SJVAB's long-term air pollution problems.

As seen in Table 3-5, operation of the alternatives would not result in an increase in O_3 precursor (NO_x) emissions above the SJVAPCD thresholds of 10 tons per year. Although the GAMAQI states that these emissions would not be considered a cumulative net increase in O_3 precursors, as noted previously, the SJVAPCD assumes air emissions to be cumulatively adverse if, with Environmental Commitments, an alternative results in any increase in a pollutant for which the SJVAB is classified as a nonattainment area. Thus, the effect is considered adverse.

Implementation of control measurements for construction emissions of PM_{10} required by SJVAPCD (Environmental Commitment AQ-1) would reduce emissions of PM_{10} associated with construction. Emissions of PM_{10}, ROG, and NO_x associated with operations would be reduced by the emission-control devices described for the propane-fueled engine. In addition, MID would shut off the diesel engines when not in use (Environmental Commitment AQ-2) to reduce the severity of the effect.

3.4 Biological Resources

This section describes the existing biological resources in the areas potentially affected by the proposed alternatives. It discusses the affected environment, relevant regulations and policies, methods of analysis, and possible effects.

3.4.1 Affected Environment

Madera Ranch is located in southwestern Madera County and encompasses 13,646 acres. The topography slopes gently downward from east to west, ranging in elevation from about 215 feet above mean sea level (feet msl) to about 175 feet msl. The site is gently undulating and traversed by numerous shallow swales that generally run from east to west.

Watersheds and Streams

Madera Ranch lies in the historical floodplain between the Fresno River and San Joaquin River, and the south side of the ranch lies in the active floodplain of Cottonwood Creek. With the exception of Sections 28 and 29, which are inundated with Cottonwood Creek water in wet years, uncontrolled flows are rare because the surrounding areas are protected by upstream reservoirs, levees, and water diversions, and upstream off-site portions of drainages have been filled in by farmer field-leveling. The average annual rainfall at Madera Ranch is approximately 11 inches, most of which falls between October and April (California Irrigation Management Information System Station #145).

The most significant water features on Madera Ranch are Cottonwood Creek and GF Canal. Cottonwood Creek is a channelized, seasonally flowing stream that crosses Madera Ranch at the southwest corner of Section 28. The Cottonwood Creek channel has been deepened and widened by excavation throughout its length on and off the ranch. Natural streamflow occurs only during the wet season, typically from January through March. During this wet season, uncontrolled flows from the creek frequently flow out onto the southern portions of Sections 28 and 29 through a berm system that was installed in the early 1990s. From April through October, MID uses Cottonwood Creek to convey and distribute San Joaquin River and Fresno River water to growers. The creek is typically dry in November and December. MID periodically removes sediment, debris, and vegetation from the creek channel and banks using a variety of heavy equipment that moves up and down the dry creek channel. The mean width of Cottonwood Creek within the ordinary high-water mark is 40 feet.

GF Canal is a 40- to 90-foot-wide, 9- to 16-foot-deep trapezoidal irrigation and uncontrolled flow conveyance canal that bisects Madera Ranch. GFWD uses GF Canal to convey agricultural water to Section 21 and part of Section 22. In the past, during above-normal water years, waters flowed through GF Canal to Avenue 12. There are several turnouts on GF Canal where water historically has been directed to flow into grassland areas in Sections 4, 9 and 16 of Madera Ranch.

Watersheds at Madera Ranch are highly localized, and most rainfall infiltrates rapidly into the ground. Historically, the swales at Madera Ranch likely received uncontrolled flows from Cottonwood Creek and other drainages south of the Fresno River. However, as surrounding lands were brought into agricultural use and leveled, these swales have been isolated from upstream sources of water, with the exception of uncontrolled flows from Cottonwood Creek onto swales in Section 28 and 29.

Plant Communities and Wildlife Habitats

Seven native and one nonnative plant communities were identified on Madera Ranch. The names of the plant communities used in this report are based on the conventions described by Sawyer and Keeler-Wolf (1995) and are used to describe the wildlife habitats. The descriptions of these communities and habitats include a listing of the representative plants and wildlife that typically occur in each area and the regional distribution of the community type in the vicinity of Madera Ranch. Table 3-9 shows the acreage of each of these communities, and Figure 3-4 shows the distribution of each community on Madera Ranch. Table 3-10 lists sensitive plants that occur or may occur at the project site.

Table 3-9 Plant Communities on Madera Ranch

Community	Approximate Size in Acres
California annual grassland	6,462
Alkali grassland	4,044
Vernal pool	22
Great Valley iodine brush scrub	292
Freshwater marsh	2
Alkali rain pool	16
Riparian woodland	2
Cultivated lands	2,745
Pond	2
Other Land-Cover Types:	
Cottonwood Creek (Canal)	4
Gravelly Ford Canal	33
Ranching facilities	22
Total	**13,618**

Table 3-10 Special-Status Plants Occurring or Potentially Occurring at Madera Ranch

Name	Status* Federal/State /CNPS	Distribution	Habitat	Occurrence in Project Area
Palmate-bracted bird's-beak *Cordylanthus palmatus*	E/E/1B	Livermore Valley and scattered locations in the Central Valley from Colusa County to Fresno County	Alkaline grasslands, chenopod scrub; blooms May–October	Unlikely to occur
Succulent owl's-clover *Castilleja campestris* ssp. *succulenta*	T/E/1B	Eastern edge of San Joaquin Valley and adjacent foothills, from Stanislaus County to Fresno County	Vernal pools; blooms April–May	Unlikely to occur (out of range)
San Joaquin Orcutt grass *Orcuttia inaequalis*	T/E/1B	Scattered locations along east edge of the San Joaquin Valley and adjacent foothills, from Stanislaus County to Tulare County	Large, deep vernal pools; blooms May–September	Suitable habitat not present
Hairy Orcutt grass *Orcuttia pilosa*	E/E/1B	Scattered locations along east edge of the Central Valley and adjacent foothills, from Tehama County to Merced County	Large, deep vernal pools; blooms May–August	Suitable habitat not present
Greene's tuctoria *Tuctoria greenei*	E/R/1B	Eastern Central Valley and foothills	Large, deep vernal pools; blooms May–June	Suitable habitat not present
Heartscale *Atriplex cordulata*	–/–/1B	Alameda, Butte, Colusa, Fresno, Glenn, Kern, Madera, Merced, San Joaquin, San Luis Obispo, Solano, Stanislaus, Tulare, and Yolo Counties	Chenopod scrub, meadows and seeps, valley foothill grassland. Blooms April-October.	Could be present and would be impacted.
Lesser saltscale *A. miniscula*	–/–/1B	Butte, Fresno, Kern, Madera, Merced, Stanislaus, and Tulare Counties	Chenopod scrub, Playas, Valley and foothill grassland/alkaline, sandy. Blooms May-October.	Could be present and would be impacted.
Vernal pool smallscale *A. persistens*	–/–/1B	Glen, Madera, Merced, Solano, Stanislaus, and Tulare Counties.	Alkaline vernal pools. Elevation 10-115 meters. Blooms June-October.	Could be present and would be impacted.
Subtle orache *A. subtillis*	–/–/1B	Butte, Fresno, Kings, Kern, Madera, Merced, and Tulare Counties	Valley and foothill grassland. Blooms June-August (October but not common).	Could be present and would be impacted.
Lost Hills crownscale *A. vallicota*	–/–/1B	Fresno, Kings, Kern, Merced, and San Luis Obispo Counties	Chenopod scrub, Valley and foothill grassland, Vernal pools/alkaline. Blooms April-August.	Unlikely to occur (out of range)
Hoover's cryptantha *Cryptantha hooverii*	E/R/1B	Contra Costa , Kern, Madera, and Stanislaus Counties	Inland dunes, Valley and foothill grassland. Blooms April-May.	Could be present and would be impacted.
Recurved larkspur *Delphinium recurvatum*	–/–/1B	Alameda, Butte, Contra Costa, Colusa, Fresno, Glenn, Kings, Kern, Madera, Merced, Monterey, San Joaquin, San Luis Obispo, Solano, and Tulare Counties	Chenopod scrub, cismontane woodland, valley and foothill grassland, alkaline substrates. Blooms March-June.	Could be present and would be impacted.
Sanford's arrowhead *Sagittaria sanfordii*	–/–1B	Butte, Del Norte, El Dorado, Fresno, Merced, Mariposa, Orange, Placer, Sacramento, Shasta, San Joaquin, Tehama, and Ventura Counties	Marshes and swamps (assorted shallow freshwater). Blooms May-October.	Suitable habitat not present

Name	Status* Federal/State /CNPS	Distribution	Habitat	Occurrence in Project Area

* Status explanations:

Federal

– = No status
E = Listed as —endangered” under the federal Endangered Species Act.
T = Listed as —threatened” under the federal Endangered Species Act.

State

– = No status
E = Listed as —endangered” under the California Endangered Species Act.
R = Listed as —rare” under the California Endangered Species Act.

California Native Plant Society

California Native Plant Society (CNPS). 2010. Inventory of Rare and Endangered Plants (online edition, v7-10c). California Native Plant Society. Sacramento, CA. Accessed on Fri, Aug. 27, 2010 from http://www.cnps.org/inventory.

1B = List 1B species: rare, threatened, or endangered in California and elsewhere.

Madera Ranch lies in the San Joaquin Valley subregion of the California Floristic Province (Hickman 1993). The local flora include 198 taxa (species, subspecies, and varieties) in 39 plant families. Nonnative species represent 53 taxa (26.8%), which is on the low end of the range (20–71%) reported for the proportion of nonnatives in other California annual grasslands (Heady 1988).

Although the surrounding land has been converted to agriculture, most of Madera Ranch is open, grazed rangeland. Rangeland vegetation consists primarily of annual grassland. Two grassland plant communities (California annual grassland and alkali grassland) and two wetland plant communities (vernal pool and alkali rain pool) are present in the annual grassland. In addition, Great Valley iodine bush scrub occurs in the northern half of Section 7. Freshwater marsh is present in portions of the channel of the GF Canal. Riparian woodland is present on the margins of a small pond in Section 28. Vineyards, orchards, and cropland are present in cultivated portions of the ranch (Figure 3-4).

California Annual Grassland California annual grassland is open grassland composed of annual grasses and forbs (Sawyer and Keeler-Wolf 1995). Although the dominant grasses are of Mediterranean or Eurasian origin, the annual and perennial herbs are mostly native to the California Floristic Province. At Madera Ranch, California annual grassland occupies sandy loam soils, primarily of the Pachappa soil series.

At Madera Ranch, characteristic species include the following:

- Soft chess (*Bromus hordeaceus*).
- Foxtail barley (*Hordeum murinum* ssp. *leporinum*).
- Rattail fescue (*Vulpia myuros*).
- Common fiddleneck (*Amsinckia menziesii*).
- Popcornflower (*Plagiobothrys canescens*).
- Johnny-tuck (*Triphysaria eriantha*).
- Blue dicks (*Dichelostemma capitata*).
- California goldfields (*Lasthenia californica*).
- Purple owl’s-clover (*Castilleja exerta*).
- Bird’s-eye gilia (*Gilia tricolor* ssp. *diffusa*).

California annual grassland is the most widespread plant community at Madera Ranch, occurring in most uncultivated areas on the ranch, in both uplands and swales.

Within the California annual grassland community, small areas of accumulated wind-blown sand derived from basin soils are characterized by showy annual wildflower species, including baby blue-eyes (*Nemophila menziesii*), California poppy (*Eschscholzia californica*), sun cup (*Camissonia campestris*), and tidy-tips (*Layia platyglossa*).

California annual grasslands have experienced historical agricultural disturbance in several areas of Madera Ranch, including Sections 14, 15, 16, 17, 18, and 22 (Figure 3-4). Grasslands in

Sections 16, 17, and 18 were disturbed more than 10 years ago, and there is little discernable difference between this habitat and areas that have not experienced agricultural production.

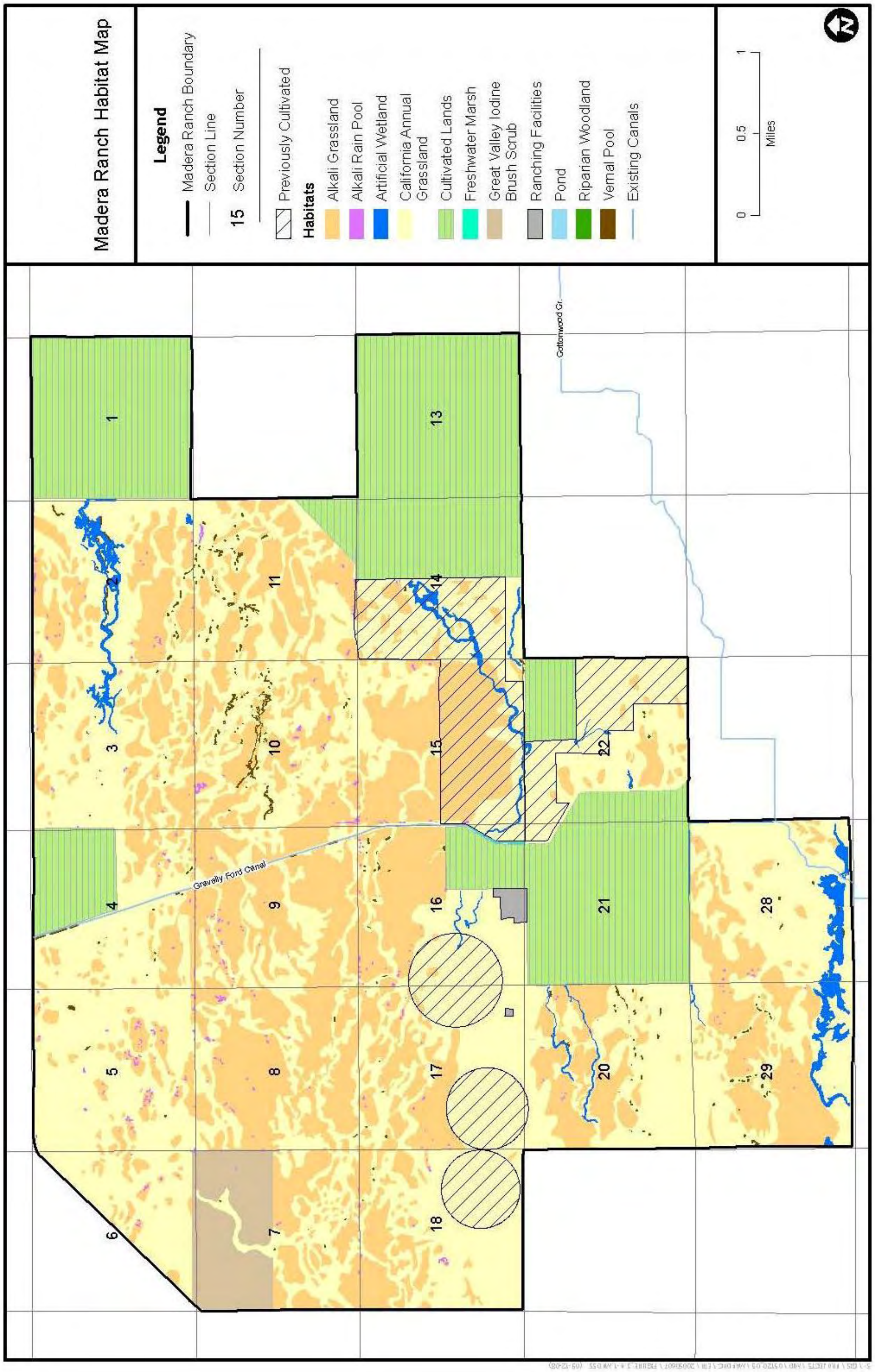


Figure 3-4 Madera Ranch Habitat Map

Grassland in Section 22 was disturbed more recently than 10 years ago, and annual grasses there are similar to undisturbed areas but have not completely recovered. Even though furrows are still present, grassland in Sections 14 and 15 is most similar to undisturbed areas. The similarities found between historically cultivated areas and undisturbed areas suggest that California annual grasslands can recover from relatively severe effects. However, there are some actions such as deep ripping of certain soil types that cannot recover.

Overall vegetative differences including density and composition may persist for many years in areas with new roads or pipelines. This is supported by the one published study based on a Central Valley site (Holmstead and Anderson 1998). In this study, some aspects of regenerating vegetation were documented for sites restored after excavations at oil fields in the southern San Joaquin Valley. On sites restored by replacing stockpiled topsoil and planting seed, vegetation was sparser (i.e., had a lower density and cover of plants) than on undisturbed sites. Sites where stockpiled topsoil was replaced but no seeds were planted had a cover and density of plants lower than the seeded sites and much lower than adjacent undisturbed areas. The species composition of the sites and their long-term recovery were not documented in this study.
On Madera Ranch, portions of the property appear to have recovered from previous disturbance within five years, such as the access roads to the test pond work areas. Also, larger tracts of land have become re-established with annual grasslands, specifically, the western ½ of Section 14, the southern ½ of Section 15, and portions of Section 16, 17, 18 and 22 were cultivated approximately 30 years ago.

Wildlife Many wildlife species use annual grassland for foraging, but these species usually require special habitat features such as burrows, rock outcrops, ponds, or habitats with shrubs or trees for breeding, resting, and escape cover. Mammals commonly found in grassland habitat include desert cottontail (*Sylvilagus audobonii*), black-tailed jackrabbit (*Lepus californicus*), Heermann’s kangaroo rat (*Dipodomys heermanni*), San Joaquin pocket mouse (*Perognathus inornatus*), California ground squirrel (*Spermophilus beecheyi*), American badger (*Taxidea taxus*), and coyote (*Canis latrans*).

Common birds known to breed in annual grasslands include western meadowlark (*Sturnella neglecta*) and California horned lark (*Eremophila alpestris actia*).

Grasslands also provide important foraging habitat for a variety of raptors including:

- red-tailed hawk (*Buteo jamaicensis*),
- northern harrier (*Circus cyaneus*),
- white-tailed kite (*Elanus leucurus*),
- American kestrel (*Falco sparverius*),
- western burrowing owl (*Athene cunicularia hypugea*),
- short-eared owl (*Asio flammeus*),
- prairie falcon (*Falco mexicanus*), and
- turkey vulture (*Cathartes aura*).

Amphibian species that typically breed in ponds and vernal pools in grassland habitat include:

- western spadefoot toad (*Scaphiopus hammondii*),
- western toad (*Bufo boreas*), and
- Pacific treefrog (*Hyla regilla*).

Characteristic reptiles that breed in grasslands include:

- western fence lizard (*Sceloporus occidentalis*),
- side-blotched lizard (*Uta stansburiana*),
- common garter snake (*Thamnophis sirtalis*), and
- gopher snake (*Pituophis melanoleucus*).

Regional Distribution California annual grassland is the typical grassland community of the California Central Valley and adjacent foothills. Although common in foothill areas, California annual grassland is regionally uncommon in the Central Valley as a result of conversion to cropland. Few areas of California annual grassland are left in Madera County west of SR 99. Therefore, California annual grassland at Madera Ranch is a sensitive plant community.

Alkali Grassland The alkali grassland community present at Madera Ranch occurs on strongly saline-alkali soils, generally of the Fresno and El Peco soil series. This plant community is uncommon and has not been characterized in the ecological literature. In addition to the typical grassland species cited above, perennial and halophytic species (species that grow in salty soils) are common. Perennial species present in the alkali grasslands include interior goldenbush (*Isocoma acradenia* var. *bracteosa*), locoweed (*Astragalus* spp.), alkali sacaton (*Sporobolus airoides*), and saltgrass (*Distichlis spicata*). The presence of these perennial species suggests that the vegetation in areas of strongly saline-alkali soils historically was a shrub community dominated by saltbush (*Atriplex* spp.) or iodine bush (*Allenrolfea occidentalis*). Except for the absence of shrubby saltbush species, the floristic composition and cover of annual grasses and forbs in alkali grassland at Madera Ranch is very similar to that of valley saltbush scrub.

Slickspots, also called alkali scalds, are common in the alkali grassland. Slickspots are relatively shallow, sparsely vegetated depressions containing strongly saline-alkali soils (Reid et al. 1993). At Madera Ranch, they are interspersed on nearly level inter-swale landforms where soils are mapped as different stages and/or complexes of the Fresno, El Peco, and Dinuba series. These soil series are strongly to slightly saline-alkali and possess a carbonate-silica cemented hardpan at depths ranging from 20 to 40 inches. The slickspots have a fringe of annual halophytic species, including common spikeweed (*Centromadia pungens*), bush seepweed (*Suaeda moquinii*), alkali peppergrass (*Lepidium dictyotum*), large-flowered sand spurry (*Spergularia macrotheca* var. *leucantha*), and annual saltscale (*Atriplex* spp.) species.

As described above under California annual grassland, some areas of alkali grassland have experienced historical agricultural disturbance. Alkali grassland was not entirely disturbed, or has recovered from these activities, and during botanical surveys it was observed in historical agricultural areas in Sections 14, 15, and 22. Alkali grasslands were much less extensive in former agricultural land in Sections 16, 17, and 18 (Figure 3-4).

Wildlife Many of the wildlife species characteristic of California annual grasslands described above are the same as those species associated with the alkali grasslands. Western burrowing owl, western meadowlark, and California horned lark are the more visible bird species of this area. Badger, coyote, and black-tailed jackrabbit also have been observed in this habitat. Regional Distribution Alkali grasslands are a sensitive plant community restricted to a few occurrences along the central trough of the Central Valley at the lower end of older alluvial fans. These alluvial fans historically received finer-textured, water-transported sediments and water-soluble salts derived from granitic rocks (San Joaquin Valley) or sedimentary and metamorphic rocks (Sacramento Valley). Areas with alkali grasslands have (or historically had) a high water table, and the capillary rise of water to the soil surface and subsequent evaporation deposits salts at or near the soil surface. Alkali grasslands are not well-documented, although areas with soils suitable for the support of alkali grasslands occur from Glenn County to Kern County. However, many of these areas of alkali soils have been converted to cropland, with scattered remnants present primarily in the National Wildlife Refuge System. In Madera County, alkali grasslands occur west of SR 99 in the area between the Fresno River and the San Joaquin River where natural vegetation is present.

Vernal Pools Vernal pools are seasonal wetlands that form in depressions, generally in annual grassland habitat. Water collects in the pool basins during winter rainfall, and extended ponding is maintained by a subsurface layer that is very slowly permeable.

At Madera Ranch, vernal pools occur in swales, primarily on soils mapped under the Pachappa series. Although a claypan or hardpan is absent, wetland hydrology is maintained by the very slow permeability of the soil surface horizons caused by the high salinity. Holland (1978) reports that vernal pools are uncommon on the soil series group that includes the Pachappa series because of the absence of a restrictive layer. Because vernal pools are so uncommon on this soil type, neither Holland (1986) nor Sawyer and Keeler-Wolf (1995) include this type of vernal pool in their plant community descriptions. Vernal pool fairy shrimp (*Branchinecta lynchi*) are present in the vernal pools at Madera Ranch.

The vernal pools at Madera Ranch are floristically similar to northern claypan vernal pools (Holland 1986; Sawyer and Keeler-Wolf 1995). They are often dominated by Mediterranean barley (*Hordeum marinum* ssp. *gussoneanum*), which is often seen in vernal pools of relatively brief ponding. Typical vernal pool endemics present in the pools include coyote thistle (*Eryngium vaseyi* var. *vallicola*), Fremont's goldfields (*Lasthenia fremontii*), California water-starwort (*Callitriche marginata*), bracted popcornflower (*Plagiobothrys bracteatus*), Pacific foxtail (*Alopecurus saccatus*), American pillwort (*Pilularia americana*), and vernal pool smallscale (*Atriplex persistens*).

Most of the vernal pools on Madera Ranch are connected by swales. The swales are shallow drainages that convey surface runoff during and immediately after storms. Swales may be an important route for dispersal of aquatic organisms between vernal pools. Because the swales at

Madera Ranch lack a duripan and the vegetation does not differ substantially from the adjacent grasslands, the swales are not distinguished as separate features on Figure 3-4.

Wildlife Vernal pools and swales provide important breeding habitat during the wet season for various wildlife species, including California tiger salamander (*Ambystoma californiense*), western spadefoot toad, and vernal pool fairy shrimp. During the wet season, dabbling ducks may use the pools, and Brewer's blackbirds (*Euphagus cyanocephalus*), common snipe (*Gallinago gallinago*), long-billed dowitcher (*Limnodromus scolopaceus*), least sandpiper (*Calidris minutilla*), and American pipits (*Anthus reubescens*) may graze and glean from pool shorelines. American avocets (*Recurvirostra americana*), California horned larks, and western meadowlarks nest in the swales and adjacent grasslands. Mourning doves (*Zenaida macroura*) and lesser nighthawks (*Chordeiles acutipennis*) may nest in the dry vernal pool beds.

Regional Distribution Northern claypan vernal pools are a sensitive plant community present at scattered locations throughout the Central Valley, generally occurring on the alluvial fan terraces along both margins of the valley but also occurring in the central trough. The distribution of northern claypan vernal pools is similar to that of alkali grasslands described above. The presence of vernal pools in Madera County west of SR 99 previously had not been documented (California Natural Diversity Database 2004), although additional vernal pools could occur on other lands where soils and vegetation are similar to those at Madera Ranch. Vernal pools have been documented in Madera County east of SR 99, but these are a different type of habitat classified as northern hardpan vernal pools.

Alkali Rain Pools Alkali rain pools are a rare type of vernal pool that has not been described in the ecological literature and appears to have been little studied. Jones & Stokes previously identified this habitat in Tulare County (Jones & Stokes Associates 1998). Alkali rain pools form in slickspots that pond water for long duration. Alkali rain pools are unvegetated except for a fringe of annual halophytic species, including bush seepweed, alkali peppergrass, dwarf popcornflower (*Plagiobothrys humistratus*), California alkali grass (*Puccinellia simplex*), large-flowered sand spurry, and annual saltscale species.

Alkali rain pools differ from other vernal pools in their vegetation, soils, and hydrology. Alkali rain pool vegetation is sparse and concentrated on the pool margins and along soil cracks. In contrast, vegetation in other vernal pools typically covers the entire pool bottom. Moreover, alkali rain pools lack plant species characteristic of vernal pools. Instead, vegetation in alkali rain pools is composed of mostly annual, halophytic/alkali-tolerant species.

Wildlife When wet, alkali rain pools on Madera Ranch provide habitat for crustaceans and other invertebrates, such as Lindahl's fairy shrimp (*Branchinecta lindahli*). Alkali fairy shrimp (*Branchinecta mackini*) and Lindahl's fairy shrimp are present in the alkali rain pools, indicating that the pH ranges from 6.9 to 9.6 (Jones & Stokes 2000). The longhorn fairy shrimp (*Branchinecta longiantenna*), a potential inhabitant of alkali rain pools, was not observed at Madera Ranch. San Joaquin tiger beetle (*Cicindela tranquebarica* ssp. undescribed) is present around the moist margins of the alkali rain pools and other slickspots. Brewer's blackbirds and a variety of shorebirds, including killdeer (*Charadrius vociferus*), common snipe (*Gallinago gallinago*), long-billed dowitcher (*Limnodromus scolopaceus*), and least sandpiper (*Calidris* *minutilla*), forage for insects along the shores of the rain pools. In the dry season, this habitat is used by many of the same species associated with the alkali grasslands and dry vernal pool beds.

Regional Distribution Alkali rain pools form a sensitive plant community that has been documented only at the Carrizo Plains, Madera Ranch, one site in Tulare County, and Semitropic Water Bank in Kern County. However, alkali rain pools are expected to occur at other locations where strongly saline/alkali soils are found. These soils occur primarily in the central trough of the Central Valley at the lower end of older alluvial fans, as described above for alkali grasslands. In Madera County, alkali rain pools are known only at Madera Ranch, although they could occur on other parcels in western Madera County where soils and vegetation are similar to those at Madera Ranch.

Great Valley Iodine Bush Scrub Great Valley iodine bush scrub is an open or dense scrub community dominated by iodine bush. In typical Great Valley iodine bush scrub, cover of annual grasses and forbs is generally low, being inhibited by a high water table and soils that are highly saline or alkali (Holland 1986). At Madera Ranch, other perennial species associated with this community include interior goldenbush, locoweed, rusty molly (*Kochia californica*), alkali sacaton, and saltgrass. The herbaceous understory of Great Valley iodine bush scrub is similar to that of alkali grassland, with a high cover of grass and forb species except where slickspots are present. On Madera Ranch, cover of annual grasses and forbs is high, consistent with the fact that the water table is no longer close to the surface (Water Resources Section).

Wildlife Wildlife species associated with this habitat include many of the same species found in the annual grassland habitat.

Regional Distribution Great Valley iodine bush scrub is a sensitive plant community reported from about 30 scattered locations in the Central Valley, ranging from Contra Costa County to Kern County (California Natural Diversity Database 2008). Most of the occurrences are found in the basins along the trough of the Central Valley, where the water table historically was high. At Madera Ranch, this plant community is present in the northern half of Section 7 (Figure 3-4). Great Valley iodine bush scrub has also been reported along Avenue 12, on property adjacent to Madera Ranch.

Freshwater Marsh Freshwater marsh is a wetland habitat dominated by emergent perennials, typically tules (*Schoenoplectus* spp.) or cattails (*Typha* spp.). Freshwater marsh occurs in the southeastern corner of Section 16 within the channel of the GF Canal (Figure 3-4). Dominant species include common bulrush (*Schoenoplectus acutus*), narrow-leaved cattail (*Typha angustifolia*), broad-leaved cattail (*T. latifolia*), and yellow cress (*Rorippa palustris*).

Wildlife Representative wildlife species favoring this habitat include the Pacific treefrog, common garter snake (*Thamnophis sirtalis*), red-winged blackbird (*Agelaius phoeniceus*), mallard (*Anas platyrhynchos*), great egret (*Ardea alba*), and great blue heron (*Ardea herodias*).

Regional Distribution Freshwater marsh is found throughout the Central Valley. Historically, freshwater marsh was extensive in the Delta and in the flood basins associated with the major river systems. Currently, the main occurrences are along sloughs associated with the larger river systems (Sacramento, San Joaquin, and others) or at wildlife refuges and duck clubs (California Natural Diversity Database 2008). Small pockets of freshwater marsh occur in many areas where standing water is present for all or much of the year, including both natural and human-made features such as irrigation and drainage canals and stock ponds. Freshwater marsh is a sensitive plant community because of state and federal policies and regulations mandating no net loss of wetlands.

Riparian Woodland Riparian woodland is an open-canopied, tree-dominated habitat occurring along streams, adjacent to lakes and ponds, or on alluvial fans or floodplains where a high water table is present. The woody canopy is generally dominated by cottonwood (*Populus* spp.) or willow (*Salix* spp.) trees. The understory may be shrubby (willows, blackberry [*Rubus* spp.], wild rose [*Rosa* spp.], buttonwillow [*Cephalanthus occidentalis* var. *californicus*]) or composed primarily of herbaceous species, such as mugwort (*Artemisia douglasiana*).

At Madera Ranch, a stand of riparian woodland is present around the margins of the small pond in the southeastern corner of Section 28 (Figure 3-4). Cottonwood and willow trees also occur along the GF Canal on the western side of Section 22.

Wildlife Riparian woodland habitat provides foraging and breeding habitat for many wildlife species. Swainson's hawk (*Buteo swainsoni*), American kestrel (*Falco sparverius*), great horned owl (*Bubo virginianus*) and mourning dove use the larger cottonwoods in this habitat for roosting and perching between foraging trips. Downy woodpecker (*Picoides pubescens*) and house finches (*Carpodacus mexicanus*) also nest in the trees.

Regional Distribution Riparian woodland occurs at scattered locations throughout the Central Valley, primarily along rivers and streams. Isolated patches of habitat occur around farm ponds or along drainage canals. In Madera County, riparian woodland occurs along the San Joaquin, Fresno, and Chowchilla Rivers. Riparian woodland is a sensitive plant community at Madera Ranch because it is locally and regionally uncommon.

Cultivated Lands Madera Ranch includes approximately 2,700 acres of land currently in agricultural production and approximately 1,500 acres of land that previously have been cultivated (Figure 3-4). Lands currently in agricultural production are planted with cotton and vineyards and lack native vegetation. Lands that have not been cultivated recently have reverted to California annual grassland and support wildlife associated with undisturbed grassland.

Other Habitats Two other habitat types found at Madera Ranch are described below. These habitats are a small pond and bird-nesting habitat. Bird-nesting habitat is located within previously described habitats and communities.

Pond A two-acre pond is located in the southeastern corner of Section 28 (Figure 3-4). The hydrology of this wetland is artificially maintained. The pond is connected to Cottonwood Creek via a culvert that was constructed in the 1990s. GFWD occasionally diverts water from Cottonwood Creek into the pond, and inflow is controlled by a gate valve. If the water level in the pond is high enough, a portion of the water stored in the pond can be returned to Cottonwood Creek when needed.

The pond is vegetated by vernal pool species and ruderal wetland species characteristic of disturbed seasonal wetlands such as stock ponds or detention basins. The species present include bracted popcornflower, purslane speedwell (*Veronica peregrina*), dock (*Rumex* spp.), weedy cudweed (*Gnaphalium luteo-album*), hyssop loosestrife (*Lythrum hyssopifolium*), and yellow cress (*Rorippa* spp.). A stand of riparian woodland dominated by Fremont cottonwood (*Populus fremontii* ssp. *fremontii*) and black willow (*Salix gooddingii*) is present around the margins. Barn swallows (*Hirundo rustica*), several species of bats (*Myotis* spp.), and common nighthawks (*Chordeiles minor*) forage over the pond, and raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), and deer mice (*Peromyscus maniculatus*) likely find food and water along the edges of the basin.

Ponds are a common habitat in the Central Valley. No sensitive plants are present in the pond at Madera Ranch.

Bird Nesting Habitat There are four distinct nesting habitats on Madera Ranch: grassland habitats, tree habitats, tule/shrub habitats, and agricultural land. Grassland nesting habitat is the most abundant on site. The diversity in soil types, frequency of burrows, and grassland cover provide several ecological niches for nesting. Key grassland nesting species on site include:

- killdeer,
- western burrowing owl,
- western meadowlark,
- California horned lark, and
- savannah sparrow (*Passerculus sandwichensis*).

Tree nesting habitat is more limited on Madera Ranch, but there are approximately two dozen trees that provide suitable nesting habitat. Most of these trees are near ranching facilities; several are along GF Canal; and another cluster of nesting trees is in the riparian woodland in Section 28.

Tule/shrub nesting habitats also are limited on Madera Ranch. Tule nesting habitat is located along GF Canal in the southeast corner of Section 16. Shrub nesting habitats are found along GF Canal and other agricultural drainage ditches (Figure 3-4). Tule/shrub nesting species on site include song sparrow (*Melospiza melodia*) and red-winged blackbird (*Agelaius phoeniceus*).

Agricultural land also can provide nesting habitat depending on the crop type and cropping patterns. Agricultural land in alfalfa production, including land in Sections 1, 4, 13, 14, 16, 21 and 22, could provide foraging habitat for tricolored blackbirds (*Agelaius tricolor*).

Threatened and Endangered Plants

Five plants listed by USFWS as threatened or endangered under the Federal ESA, or species that are candidates for possible future listing as threatened or endangered under ESA, are known to occur in the vicinity of Madera Ranch: palmate-bracted bird’s-beak (*Cordylanthus palmatus*), succulent owl’s-clover, San Joaquin Orcutt grass, hairy Orcutt grass, and Greene’s tuctoria. None of these species was located on Madera Ranch during the botanical surveys.

Palmate-Bracted Bird's-Beak Palmate-bracted bird's-beak is a federally and state-listed endangered species that was collected along Firebaugh-Madera Road in 1937 (California Natural Diversity Database [CNDDB] 2008). Sections 6 and 7 are adjacent to the location of this occurrence. Palmate-bracted bird's-beak grows in chenopod scrub and alkali meadows in association with iodine bush, common glasswort (*Salicornia subterminalis*), bush seepweed, western borax-weed, saltgrass, alkali heath, common spikeweed, and low barley (California Natural Diversity Database 2008). This habitat occurs in the northern half of Section 7. Consultant biologists surveyed the northern half of Section 7 and detected no palmate-bracted bird's-beak. However, there remains a possibility that palmate-bracted bird's beak is present in the seed bank and in other alkali grassland areas (Cypher pers. comm.).

Succulent Owl's-Clover Succulent owl's-clover (*Castilleja campestris* ssp. *succulenta*) is federally listed as threatened and state-listed as endangered. It occurs in northern hardpan vernal pools in association with coyote thistle (*Eryngium castrense*), stipitate popcornflower (*Plagiobothrys stipitatus*), white-headed navarretia (*Navarretia leucocephala*), Fremont's goldfields, tricolor monkeyflower (*Mimulus tricolor*), woolly marbles, and downingia (*Downingia* spp.) (California Natural Diversity Database 2008). Madera Ranch is outside the known range for succulent owl's-clover, and northern hardpan vernal pools, which are habitat for the species, do not occur on Madera Ranch. Therefore, succulent owl's-clover is presumed to be absent from the site.

Orcutt Grasses Three Orcutt grasses (San Joaquin Orcutt grass [*Orcuttia inaequalis*], hairy Orcutt grass [*Orcuttia pilosa*], and Greene's tuctoria [*Tuctoria greenei*]) are present in the Madera Ranch vicinity. San Joaquin Orcutt grass is federally listed as threatened and state-listed as endangered. Hairy Orcutt grass is both federally and state-listed as endangered. Greene's tuctoria is federally listed as endangered and state-listed as rare. All three species occur in large, deep northern hardpan vernal pools (California Natural Diversity Database 2008). Madera Ranch is outside of the known range for these three species, and northern hardpan vernal pools, which are habitat for the species, do not occur on Madera Ranch. Therefore, most Orcutt grasses are presumed to be absent from the site. However, there remains a possibility that Greene's tuctoria is present (Cypher pers. comm.).

Threatened, Endangered, and Other Sensitive Wildlife

Table 3-11 lists the federally listed wildlife species that occur, or potentially could occur, at Madera Ranch. The listing status, distribution, habitat requirements, and estimated probability of occurrence at Madera Ranch are also presented. There is no designated critical habitat on Madera Ranch.

Table 3-11 Special-Status Wildlife Species Occurring or Potentially Occurring at the Project Site

Species Name	Status* Fed/State	California Distribution	Habitat Requirements	Occurrence on Madera Ranch
Invertebrates				
Vernal pool fairy shrimp *Branchinecta lynchi*	T/–	Central Valley, interior North and South Coast Ranges; from Tehama County to Santa Barbara County; isolated populations also in Riverside County	Vernal pools; also found in sandstone rock outcrop pools	Documented in vernal pools on Madera Ranch
Vernal pool tadpole shrimp *Lepidurus packardi*	E/–	Shasta County to Merced County	Vernal pools and ephemeral stock ponds	Not recorded from Madera County. Not found during surveys
Conservancy fairy shrimp *Branchinecta conservatio*	E/–	Disjunct occurrences in Solano, Merced, Tehama, Butte, and Glenn Counties	Large, deep vernal pools in annual grasslands	Not recorded from Madera County. Not found during surveys
Longhorn fairy shrimp *Branchinecta longiantenna*	E/–	Eastern margin of South Coast Ranges from Contra Costa County to San Luis Obispo County and in Merced County	Small, clear to moderately turbid, clay- or grass-bottomed pools in sandstone rock outcrops	Not recorded from Madera County. Not found during surveys
Mid-valley fairy shrimp *Branchinecta mesovalliensis*	–/–	Sacramento, Solano, Contra Costa, San Joaquin, Madera, Merced, and Fresno Counties	Shallow vernal pools; vernal swales; and various artificial ephemeral wetland habitats, including roadside puddles, scrapes, and ditches	Not found during surveys
Insects				
San Joaquin tiger beetle *Cicindela tranquebarica* ssp.	–/–	San Joaquin Valley and Carrizo Plain	Alkali and clay flats, sand dunes, sand bars, beeches, and sandy soils	Documented on Madera Ranch
Amphibians				
Western spadefoot *Scaphiopus hammondii*	–/SSC	Sierra Nevada foothills, Central Valley, Coast Ranges, coastal counties in southern California	Shallow streams with riffles and seasonal wetlands, such as vernal pools in annual grasslands and oak woodlands	Widespread occurrence in Madera County. Documented on Madera Ranch during surveys
California tiger salamander *Ambystoma californiense* (=*A. tigrinum* c.)	T/-	Central Valley, including Sierra Nevada foothills below approximately 1,000 feet, and coastal regions; from Butte County south to Santa Barbara County	Small ponds, lakes, or vernal pools in grasslands and oak woodlands for larvae; rodent burrows, rock crevices, or fallen logs for cover for adults and for summer dormancy	Widespread occurrence in Madera County. Not found during surveys but suitable habitat occurs on Madera Ranch
Reptiles				
Blunt-nosed leopard lizard *Gambelia* (=*Crotaphytus*) *sila*	E/E, FP	San Joaquin Valley from Stanislaus County through Kern County and along eastern edges of San Luis Obispo and San Benito Counties	Open habitats with scattered low bushes on alkali flats, and low foothills, canyon floors, plains, washes, and arroyos; substrates may range from sandy or gravelly soils to hardpan	Historically documented on-site in Sections 5 and 29; suitable habitats present in slickspots and other open habitats on Madera Ranch; transect surveys conducted in May 2009 confirmed that this species is present

Species Name	Status* Fed/State	California Distribution	Habitat Requirements	Occurrence on Madera Ranch
Giant garter snake *Thamnophis gigas*	T/T	Central Valley from Fresno north to Gridley/Sutter Buttes area; has been extirpated from areas south of Fresno	Sloughs, canals, and other small waterways where there is a prey base of small fish and amphibians; requires grassy banks and emergent vegetation for basking and areas of high ground protected from flooding during winter	Documented at Mendota Pool; but not found during surveys on Madera Ranch. Unlikely to occur there because of limited and marginal habitat and lack of connectivity to populations outside Madera Ranch
California horned lizard *Phrynosoma coronatum frontale*	–/SSC	Sacramento Valley, including foothills, south to southern California; Coast Ranges south of Sonoma County; below 4,000 feet in northern California	Grasslands, brushlands, woodlands, and open coniferous forests with sandy or loose soil; requires abundant ant colonies for foraging	Widespread occurrence in Madera County. Suitable habitat on Madera Ranch, but none observed during wildlife surveys
Silvery legless lizard *Anniella pulchra pulchra*	–/SSC	Along Coast, Transverse, and Peninsular Ranges from Contra Costa County to San Diego County, with spotty occurrences in San Joaquin Valley	Habitats with loose soil for burrowing or thick duff or leaf litter (often forages in leaf litter at plant bases); may be found on beaches, sandy washes, and in woodland, chaparral, and riparian areas	Possible occurrence. Documented in San Joaquin Valley. Is a subterranean species. Suitable habitat exists on Madera Ranch
Birds				
Swainson's hawk *Buteo swainsoni*	–/T	Lower Sacramento and San Joaquin Valleys, Klamath Basin, and Butte Valley; highest nesting densities occur near Davis and Woodland, Yolo County	Nests in oaks or cottonwoods or near riparian habitats; forages in grasslands, irrigated pastures, and grainfields	Nesting pairs documented in the center of the property; high potential to use Madera Ranch for foraging
Mountain plover *Charadrius montanus*	PT/SSC	Does not breed in California; in winter, found in Central Valley south of Yuba County, along the coast in parts of San Luis Obispo, Santa Barbara, Ventura, and San Diego Counties and in parts of Imperial, Riverside, Kern, and Los Angeles Counties	Open plains or rolling hills with short grasses or very sparse vegetation; nearby bodies of water are not needed; may occupy newly plowed or sprouting grainfields	Documented in nearby areas of San Joaquin Valley; may occur seasonally on Madera Ranch but not known to breed there
White-tailed kite *Elanus leucurus*	–/FP	Yearlong resident in coastal and valley lowlands, closely associated with agricultural areas	Inhabits herbaceous and open spaces of most habitats in cismontane California	Documented in and probably nests on Madera Ranch
Ferruginous hawk *Buteo regalis*	–/SSC	Does not nest in California; winter visitor along the coast from Sonoma County to San Diego County, eastward to Sierra Nevada foothills and southeastern deserts, Inyo-White Mountains, plains east of Cascade Range, and Siskiyou County	Open terrain on plains and in foothills where ground squirrels and other prey are available	Documented on Madera Ranch. Seasonal occurrence during migration only. Good foraging habitat on Madera Ranch, but does not breed there

Species Name	Status* Fed/State	California Distribution	Habitat Requirements	Occurrence on Madera Ranch
Long-billed curlew *Numenius americanus*	–/SSC	Nests in northeastern California in Modoc, Siskiyou, and Lassen Counties; winters along the coast and in interior valleys west of Sierra Nevada	Nests in high-elevation grasslands adjacent to lakes or marshes; during migration and in winter, frequents coastal beaches, mudflats, interior grasslands, and agricultural fields	Documented on Madera Ranch; winter foraging flocks. Does not breed on Madera Ranch
Western burrowing owl *Athene cunicularia*	–/SSC	Lowlands throughout California, including Central Valley, northeastern plateau, southeastern deserts, and coastal areas; rare along South Coast	Level, open, dry, heavily-grazed or low-stature grassland or desert vegetation with available burrows	Nesting pairs documented throughout upland habitats on Madera Ranch. Extensive foraging habitat on Madera Ranch
Loggerhead shrike *Lanius ludovicianus*	C/SSC	Resident and winter visitor in lowlands and foothills throughout California; rare on coastal slope north to Mendocino County, occurring only in winter	Open habitats with scattered shrubs, trees, posts, fences, utility lines, or other perches	Documented on and likely breeds on Madera Ranch
Tricolored blackbird *Aglaius tricolor*	–/SSC	Permanent resident in Central Valley from Butte County to Kern County; breeds at scattered coastal locations from Marin County south to San Diego County and at scattered locations in Lake, Sonoma, and Solano Counties; rare nester in Siskiyou, Modoc, and Lassen Counties	Nests in dense colonies in emergent marsh vegetation, such as tules and cattails, or upland sites with blackberries, nettles, thistles, and grainfields; habitat must be large enough to support 50 pairs; probably requires water at or near nesting colony	Documented on Madera Ranch; high-quality foraging habitat throughout uplands. Nomadic breeder, so occurrence on Madera Ranch is probably irregular
Golden eagle *Aquila chrysaetoss*	–/FP	Nests in Siskiyou, Modoc, Trinity, Shasta, Lassen, Plumas, Butte, Tehama, Lake, and Mendocino Counties and in Lake Tahoe Basin; reintroduced into central coast; winter range includes the rest of California, except southeastern deserts, very high altitudes in Sierra Nevada, and east of Sierra Nevada south of Mono County	In western North American, inhabits mountain forests and open grasslands. Breeds from Alaska east across northern Canada south to Mexico, Canadian prairie provinces, and Labrador.	Documented in foraging on grasslands
Bald eagle *Haliaeetus leucocephalus*	D/E, FP	Nests in Siskiyou, Modoc, Trinity, Shasta, Lassen, Plumas, Butte, Tehama, Lake, and Mendocino Counties and in Lake Tahoe Basin; reintroduced into central coast; winter range includes the rest of California, except southeastern deserts, very high altitudes in Sierra Nevada, and east of Sierra Nevada south of Mono County	In western North America, nests and roosts in coniferous forests within 1 mile of a lake, reservoir, stream, or the ocean	Documented in Madera County; lack of habitat on Madera Ranch; could potentially forage for waterfowl using artificial pond and proposed recharge basins

Species Name	Status* Fed/State	California Distribution	Habitat Requirements	Occurrence on Madera Ranch
American peregrine falcon *Falco peregrinus anatum*	-E/ FP	Permanent resident along North and South Coast Ranges; may summer in Cascade and Klamath Ranges and through Sierra Nevada to Madera County; winters in Central Valley south through Transverse and Peninsular Ranges and plains east of Cascade Range	Nests and roosts on protected ledges of high cliffs, usually adjacent to lakes, rivers, or marshes that support large prey populations	Documented in Madera County. May occur incidentally on Madera Ranch while foraging
Mammals				
San Joaquin pocket mouse *Perognathus inornatus*	–/–	Eastern side of San Joaquin Valley	Grasslands and oak savannas with friable soils	Documented on Madera Ranch and in Madera County near project site
Fresno kangaroo rat *Dipodomys nitratoides exilis*	E/E	Fresno and Madera Counties y only	Found in alkali-sink habitats at elevations from 200 to 300 feet	Historic records of occurrence adjacent to Madera Ranch. Potential burrows for this species present throughout upland habitats on Madera Ranch, although extensive surveys revealed no Fresno kangaroo rats. No extant populations of this species are known
San Joaquin kit fox *Vulpes macrotis mutica*	E/T	Principally occurs in San Joaquin Valley and adjacent open foothills to the west; recent records show this species present in 17 counties, extending from Kern County north to Contra Costa County	Saltbush scrub, grasslands, oak, savannas, and freshwater scrub	Documented in Madera County near Madera Ranch; suitable burrow sites were present in every section, but no positive evidence of occurrence obtained during wildlife surveys
Nelson's antelope ground squirrel *Ammospermophilus nelsoni*	–/T	Western side of San Joaquin Valley from southern Merced County south to Kern and Tulare Counties; also found on Carrizo Plain in San Luis Obispo County and Cuyama Valley in San Luis Obispo and Santa Barbara Counties	Arid grasslands from 200 to 1,200 feet in elevation, with loamy soils and moderate shrub cover of Atriplex and other shrub species	Madera Ranch is within subspecies' historical range, but no documented occurrences. None observed during extensive wildlife surveys on Madera Ranch. Not likely to occur there

Species Name	Status* Fed/State	California Distribution	Habitat Requirements	Occurrence on Madera Ranch

*Species status definitions

Federal

E = listed as endangered under the federal ESA.
T = listed as threatened under ESA.
PT = proposed for federal listing as threatened under ESA.
PD = federally proposed for delisting.
– = no listing.

State

E = listed as endangered under the California Endangered Species Act (CESA).
T = listed as threatened under CESA.
FP = fully protected under the California Fish and Game Code.
SSC = species of special concern in California.
– = no listing.

Sources: California Natural Diversity Database 2004 and Jones and Stokes file data.

The two federally listed species documented as occurring on Madera Ranch during the biological surveys are vernal pool fairy shrimp and blunt-nosed leopard lizard. Surveys in 2009 resulted in blunt-nosed leopard lizard sightings in sections 3, 10, 14, and 15.

San Joaquin kit foxes have been documented previously near Madera Ranch, but none were seen on the property during the surveys conducted for this study. The grassland habitats of Madera Ranch provide suitable habitat for Fresno kangaroo rats, and records from CNDDB and university museum collections show this area to be within the historical distributional range of this species. However, the field transect and trapping surveys conducted for this study did not document the presence of Fresno kangaroo rats at Madera Ranch. It should be noted that a property-wide trapping survey was conducted for the Fresno kangaroo rat in 2000, but a more intensive trapping survey was conducted in 2009 only for that portion of Madera Ranch lying east of the GF Canal.

Additionally, none of the following species was documented during surveys conducted to date, although limited suitable habitat is present for them at Madera Ranch:

- vernal pool tadpole shrimp (*Lepidurus packardi*),
- Conservancy fairy shrimp (*Branchinecta conservatio*),
- mid-valley fairy shrimp (*Branchinecta mesovallensis*),
- California tiger salamander, (*Ambystoma californiense* [=*A. tigrinum* c.])
- California horned lizard (*Phrynosoma coronatum frontale*),
- silvery legless lizard (*Anniella pulchra pulchra*), and
- American peregrine falcon (*Falco peregrinus*)

Invertebrates
Vernal Pool Fairy Shrimp The vernal pool fairy shrimp is listed as threatened under ESA. Vernal pool fairy shrimp were documented in several pools on Madera Ranch during reconnaissance surveys. Vernal pool and alkali rain pool habitat on Madera Ranch is potentially suitable for this species. Wetland areas with greater disturbance, like those in GF Canal and near the property boundary in Section 28, are less likely to support this species because of agricultural contamination (Figure 3-4).

Vernal Pool Tadpole Shrimp The vernal pool tadpole shrimp is listed as threatened under ESA. Vernal pool and alkali rain pools are the most suitable habitat for this species on Madera Ranch, but no tadpole shrimp have been documented.

Conservancy Fairy Shrimp The Conservancy fairy shrimp is a federally listed endangered species. In contrast to the habitat requirements of vernal pool fairy shrimp and vernal pool tadpole shrimp, vernal pool and alkali rain pool habitat on Madera Ranch is least suitable for Conservancy fairy shrimp because the species normally inhabits large, turbid pools called playa pools (Eriksen and Belk 1999; Vollmar 2002), and there are few of these large, turbid pools on the Madera Ranch site. No Conservancy fairy shrimp have been documented in the Madera Ranch area. However, there remains a possibility that this species is present on the property (Owens pers. comm.). Recently, small pools at the Sandy Mush Conservation Bank in Merced

County have been found to have Conservancy fairy shrimp, therefore the species is assumed to potentially be present in any of the vernal and alkali rain pools on Madera Ranch.

Mid-Valley Fairy Shrimp The mid-valley fairy shrimp is not listed under ESA. The USFWS recently reviewed a petition to list this species and determined that listing is not warranted at this time. Its habitat requirements are similar to those of vernal pool fairy shrimp and vernal pool tadpole shrimp, but the species has not been documented at Madera Ranch.

San Joaquin Tiger Beetle The San Joaquin tiger beetle is not a federally or state-listed species but is considered sufficiently rare by the scientific community to qualify for such listing. Most habitats on Madera Ranch are suitable for this species, although alkali scalds and vernal pools are most suitable because these habitat types provide foraging opportunities (Figure 3-4). Several live individuals, one dead individual, and other signs of beetle activity were documented at Madera Ranch.

Amphibians

Western Spadefoot Toad The western spadefoot toad is designated as a species of special concern by DFG. Western spadefoot toad tadpoles were observed in GF Canal in 2000, in Sections 4 and 9. Vernal and alkali rain pools are potential breeding and estivation habitat for this species. Wetlands near the property boundary in Section 28 are less likely to support this species because of their connectivity to other sources of water that support mosquitofish (*Gambusia affinis*) and bullfrogs (*Rana catesbeiana*) (Figure 3-4).

California Tiger Salamander The California tiger salamander is federally listed as threatened. Vernal and alkali rain pools are potential breeding habitat for this species, and upland areas within approximately 1 mile of a wetland are potential nonbreeding areas. Madera Ranch has suitable habitat for this species and is within its historical distribution range, but no evidence of California tiger salamanders was found during reconnaissance surveys conducted for amphibians while surveying for vernal pool crustaceans.

California Red-Legged Frog The California red-legged frog is federally listed as threatened. The California red-legged frog was likely never common on the valley floor, and subsequent habitat destruction and modification, as well as many years of pesticide use, appear to have extirpated the species from this portion of its former range. No habitat in the potentially affected area was considered suitable for this species.

Reptiles

Blunt-Nosed Leopard Lizard The blunt-nosed leopard lizard is listed as endangered under California Endangered Species Act (CESA) and ESA and as a fully protected species under the California Fish and Game Code. Historical records indicate the presence of blunt-nosed leopard lizard in the vicinity of Madera Ranch and on Madera Ranch in 1987. The approximately 4,044 acres of alkali grassland habitat and high kangaroo rat burrow density make much of Madera Ranch suitable for blunt-nosed leopard lizard (Table 3-9 and Figure 3-4). Transect surveys conducted in May 2009 confirmed that this species is present.

Giant Garter Snake The giant garter snake is listed as threatened under CESA and ESA. The giant garter snake has been documented at Mendota Pool (California Natural Diversity Database 2004), but no records of this species have been documented on Madera Ranch. Although limited marginal habitat for this species exists along the GF Canal in Section 16, it is not viably connected with any areas of documented occurrences in the vicinity (Figure 3-4). The giant garter snake was not located during surveys and is not likely to occur in this area. Similarly, because of significant regional population declines, no extant records within Madera County, the prolonged periods of dryness, seasonal fluctuation of water, and lack of consistent prey base, giant garter snake is unlikely to be within the canals of Mendota Wildlife Management Area (MWMA).

California Horned Lizard The California horned lizard is a California species of special concern. The Madera Ranch area is in the historical range of the California horned lizard, and the property contains suitable habitat, although none was observed during extensive transect surveys.

Silvery Legless Lizard The silvery legless lizard is listed as a California species of special concern. Madera Ranch is within the historical range of the silvery legless lizard and includes suitable habitat. Silvery legless lizards live primarily in the soil and would not have been readily detected during the field surveys conducted during summer 2000.

Birds

Swainson's Hawk The Swainson's hawk is listed as threatened under CESA. Nesting sites and potential breeding Swainson's hawk pairs have been documented on Madera Ranch near ranch headquarters in Section 16. All habitats on Madera Ranch provide suitable foraging habitat from March through September when the species may be present. There is limited nesting habitat because of the relatively few trees on site (Figure 3-4), but the site has definitely been used by a limited number of Swainson's hawks.

White-Tailed Kite The white-tailed kite is designated as a fully protected species under the Fish and Game Code. The white-tailed kite nests in all 14 ecological zones throughout its range in California. Madera Ranch is located in one of these zones, and pairs of kites have been sighted on the property and could be present year-round. It could breed in the Fremont cottonwoods in Section 28 or other mature trees around the ranch. Annual and alkali grasslands provide suitable foraging habitat for this species (Figure 3-4).

Ferruginous Hawk The ferruginous hawk is designated as a state species of special concern by DFG. Ferruginous hawks were documented at Madera Ranch during the October, November, and December 2000 and January 2001 surveys. It is a migratory visitor to this area and does not breed there. Annual and alkali grasslands provide suitable foraging habitat for this species (Figure 3-4).

Long-Billed Curlew The long-billed curlew is designated as a bird of conservation concern by USFWS and a species of special concern by DFG. A wintering population of approximately 200 long-billed curlews has been documented from October to March on Madera Ranch. Annual and alkali grasslands provide suitable habitat for foraging or rest during wintering migration (Figure 3-4), but the long-billed curlew is not expected to nest at Madera Ranch.

Western Burrowing Owl The western burrowing owl is designated as a species of special concern by DFG and is covered under the MBTA. Numerous burrowing owls were observed and documented at Madera Ranch during transect surveys. Annual and alkali grasslands provide suitable foraging and nesting habitat for this species (Figure 3-4).

Loggerhead Shrike The loggerhead shrike is a federal bird of conservation concern and a state species of special concern. Loggerhead shrikes have been documented throughout the Madera Ranch area. Annual and alkali grasslands provide suitable foraging habitat, and some nesting habitat exists along GF Canal and cultivated portions of the property (Figure 3-4).

Tricolored Blackbird The tricolored blackbird is designated as a state species of special concern by DFG. It is also designated as a migratory nongame bird of management concern by USFWS. The Madera Ranch area is in the historical range of the tricolored blackbird, and the ranch contains suitable habitat. Several hundred tricolored blackbirds were documented foraging between the agricultural land and grassland in Section 16. There is very little wetland breeding habitat, although other habitat (such as blackberry thickets) may be used for breeding; however, there is ample foraging habitat in the alfalfa fields to support a large breeding colony of thousands of pairs (Figure 3-4). This species tends to be nomadic in its breeding, selecting different locations different years depending on suitability and availability of the habitat.

Golden Eagle The golden eagle is a fully protected species by DFG and is federally protected under the BGEPA. Golden eagles have been detected periodically foraging on Madera Ranch.

Bald Eagle The bald eagle is federally protected under the BGEPA, is endangered under CESA, and is a fully protected species under the California Fish and Game Code. Bald eagles could periodically forage on Madera Ranch, but regionally have primarily been found foraging and nesting around Millerton Lake.

American Peregrine Falcon The American peregrine falcon has been removed from the ESA Threatened and Endangered list however it is designated as a fully protected species, pursuant to the Fish and Game code [FGC §3511 (b)(1)] under CESA. No American peregrine falcons were observed on Madera Ranch during the October, November, and December 2000 and January 2001 wintering bird surveys. All habitats on Madera Ranch, particularly the annual and alkali grasslands (Figure 3-4), provide suitable foraging habitat for this species. This species is not likely to breed on Madera Ranch.

Mammals

San Joaquin Pocket Mouse The San Joaquin pocket mouse is not a federally or state-listed species but is considered sufficiently rare by the scientific community to qualify for such listing. Annual and alkali grasslands provide suitable habitat for this species, and San Joaquin pocket mice were captured throughout Madera Ranch during small mammal trapping (Figure 3-4).

Fresno Kangaroo Rat The Fresno kangaroo rat was state-listed as endangered on October 20, 1980, and federally listed as endangered on January 30, 1985. Madera Ranch has suitable grassland habitat for Fresno kangaroo rats, but none have been identified on Madera Ranch, despite two live trapping surveys conducted in suitable habitat on Madera Ranch. The first survey was a property-wide survey conducted in 2000, and the other was conducted only east of GF Canal in 2009. Much of the habitat on Madera Ranch is homogeneous, likely a result of the long history of cattle grazing, making the property less suitable for the Fresno kangaroo rat. The most recent surveys show that the species is not currently present east of GF Canal. Currently, no extant populations or individuals are known to exist anywhere.

San Joaquin Kit Fox The San Joaquin kit fox was listed as endangered by the USFWS in 1967 and by the state in 1971. San Joaquin kit foxes have been previously documented in Madera County near Madera Ranch (T12S R14E) (California Natural Diversity Database 2004), but none on Madera Ranch during transect, spotlighting, or camera/bait station surveys. Numerous burrow dens potentially suitable for kit fox were observed in every section of Madera Ranch during the surveys, but none of them contained direct evidence of kit fox occupancy (e.g., scat, fur, natal pups, etc.).

Documentation of Biological Resources at Madera Ranch

Biologists documented biological resources at Madera Ranch through a phased series of surveys, beginning with reconnaissance-level surveys and concluding with focused and intensive surveys. To prepare for this survey effort, biologists:

- identified applicable state, federal, and local regulations governing protection of biological resources at Madera Ranch, including off-site canals;
- conducted computer searches of the CNDDB (California Natural Diversity Database 2008) and the California Native Plant Society's Electronic Inventory (California Native Plant Society 2007) to obtain information on the presence of threatened and endangered plant and wildlife species and sensitive communities at or in the vicinity of Madera Ranch and off-site canals;
- consulted the USFWS, DFG, and local experts to obtain additional information on the status of threatened and endangered species in the Madera Ranch vicinity, and off-site canals;
- obtained and reviewed applicable scientific literature and environmental reports germane to describing and evaluating the status of biological resources on Madera Ranch and off-site canals; and
- reviewed the USGS topographic map (Bonita Ranch 7.5-minute quadrangle) and soil survey map for Madera County (Stromberg 1951). Madera Ranch is in T12S, R16E, and includes Sections 1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 13, 14, 15, 16, 17, 18, 20, 21, 22, 28, and 29 and the southeast half of Section 6. Because much of the natural resource setting references these Public Land Survey System section numbers, Figure 3-4 provides a graphical illustration of the location of each section throughout the property.

Field Surveys Field surveys were designed to lay the foundation for determining the presence and abundance of threatened and endangered species. The specific goals of these surveys were to:

- document the actual and potential occurrence and distribution of threatened and endangered plants and animals on Madera Ranch,
- evaluate Madera Ranch in terms of its overall habitat quality and potential to support threatened and endangered species, and
- provide a summary and conclusions for biological constraints to be considered in an alternatives analysis and for effect analysis.

During February–April 2000, Consultant biologists conducted reconnaissance-level surveys at Madera Ranch (Jones & Stokes 2000). Additional detailed surveys were conducted during June – November 2000 and in April 2001. In May 2009 biological consultants initiated additional surveys for wildlife. Consultant biologists conducted detailed surveys of facility corridors for plants in April 2009. Wetland delineations also were conducted in 2000 and 2005 to map and characterize wetlands occurring in the project area, with an update in 2009. As discussed in more detail below, these surveys included:

- reconnaissance-level surveys to characterize habitats present in the project area,
- delineation of wetlands and identification of vernal swales that contribute to the wetlands and vernal pools,
- focused plant surveys to identify areas that likely contain threatened and endangered plants on portions of Madera Ranch where these plants have not yet been identified,
- detailed-transect wildlife surveys to identify and evaluate habitat conditions and document the actual and potential occurrence of sensitive species throughout Madera Ranch, and
- focused surveys for Fresno kangaroo rat and San Joaquin kit fox.

Results of the botanical and wildlife surveys are summarized in Existing Conditions below. Details of the survey results have been documented previously (Jones &Stokes 2000, 2008). The spring 2009 surveys were documented in summer 2009.

Botanical Surveys Plant surveys included reconnaissance visits to the site, aerial photo interpretation, field surveys for threatened and endangered plants, and delineation of wetlands. The entire Madera Ranch property was assessed with reconnaissance-level surveys and photo interpretation.

Botanists performed reconnaissance-level surveys of the entire Madera Ranch property – other than cultivated areas (Sections 1, 13, 21, the eastern half of Section 14, the northeastern quarter of Sections 4 and 22, the southeastern quarter of Section 16, and the western edge of Section 22) – in February and March 2000. The purpose of the surveys was to become familiar with Madera Ranch and plant communities and to determine the appropriate survey protocols for the sensitive species surveys. Sections 15, 16, 17, 20, 21, 22, 28, and 29 were surveyed following the guidelines for assessing effects of proposed developments on rare and endangered plants and plant communities (California Department of Fish and Game 2000a). Early-blooming-season floristic surveys were performed during the week of April 3–7, 2000. In addition to conducting the floristic inventory, the survey team characterized the plant communities present and mapped the wetlands. Surveys for summer-blooming species were conducted on June 5 and 6, 2000, focusing on habitat for the summer-blooming species identified during the April surveys. On June 27, 2000, the northern half of Section 7 was surveyed for palmate-bracted bird's-beak. The northern half of Section 7 was the only potential habitat area identified for this endangered species. Reference locations were not visited.

Biologists completed additional fieldwork during 2005 focused on two issues: (1) additional wetland delineation surveys conducted in response to comments from the Corps and (2) reconnaissance-level habitat evaluations of proposed facilities locations outside of Madera Ranch. The wetland delineation work was intended to ground-truth the results of aerial interpretation work conducted previously and to provide additional data points for evaluating wetlands across the entire Madera Ranch site. Reconnaissance-level habitat evaluations were conducted for facilities that would be constructed along the Main No. 2 Canal, Cottonwood Creek, 24.2 Canal, and Section 8 Canal. These locations are beyond the boundaries of Madera Ranch and had not been surveyed previously.

Biologists conducted detailed walking transect surveys on April 14 and 15, 2009, with two botanists walking 30 feet apart throughout the Phase 1 facility corridors. These spring surveys did not reveal any federally or state-listed plant species. Additional late season surveys were conducted in July 2009 and those surveys also didn't result in any observations of listed plants.

Wildlife Surveys Wildlife surveys included:

- six reconnaissance visits to the site;
- more than 320 miles of walking transect surveys looking for blunt-nosed leopard lizards (*Gambelia sila*), San Joaquin kit fox burrows, kangaroo rat (*Dipodomys* spp.) burrows, burrowing owl (*Athene cunicularia hypugea*) burrows, and other sensitive species;
- 10 nights of spotlighting for kit fox;
- 45 camera/bait stations and 442 camera nights of surveys for kit fox;
- 11,120 trap nights for kangaroo rats;
- fairy shrimp sampling; and
- surveys for wintering birds.

Figure 3-5 includes an overview of the phased project facilities in relation to habitat types within the Proposed Action area.

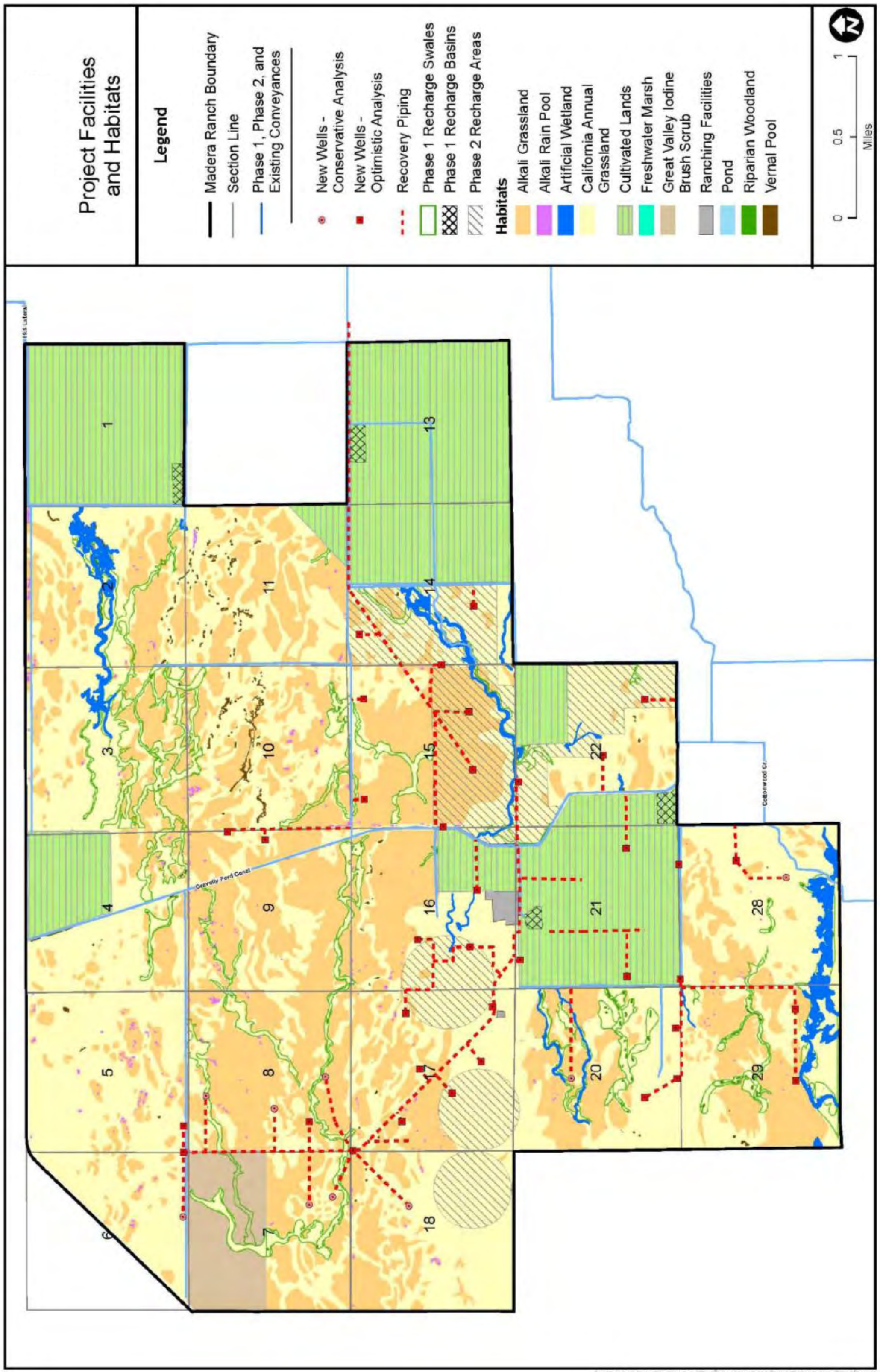


Figure 3-5 Project Facilities and Habitat within Proposed Action Area

A summary of Proposed Action habitat effects within Madera Ranch by project alternatives is included in Table 3-12.

Table 3-12 Effects of Proposed Action Alternatives on Madera Ranch Habitat

Habitat	Effect (acres[a])			
	Flooding Swales	Temporary Construction Effects	Permanent Construction Effects[b]	No Anticipated Effect
Alternative B				
California annual grassland	660	178	790	4,850
Alkali grassland	30	100	230	3,698
Vernal pool	5.5	0.04	0.1	15.8
Great Valley iodine brush scrub	10	0	0	280
Freshwater marsh	No effect	0.1	2.0	0
Alkali rain pool	0.4	1.0	1.1	13.1
Riparian woodland	No effect	No effect	2	2
Cultivated lands	No effect	70	60	2,615
Pond	No effect	No effect	No effect	2
Total	**705.9**	**349.14**	**1085.2**	**11,476**
Reduced Alternative B				
California annual grassland	508	192	396	6,462
Alkali grassland	30	80	42	4,044
Vernal pool	1.3	0.2	0	22
Great Valley iodine brush scrub	10	0	0	292
Freshwater marsh	No effect	0.1	2	2
Alkali rain pool	0.4	0.6	1.8	16
Riparian woodland	No effect	0	0	2
Cultivated lands	No effect	70	60	2,745
Pond	No effect	0	0	2
Total	**549.7**	**343.9**	**501**	**13,587**
Alternative C				
California annual grassland	No effect	178	790	5,510
Alkali grassland	No effect	100	230	3,728
Vernal pool	No effect	0.04	0.1	26.8
Great Valley iodine brush scrub	No effect	0	0	290
Freshwater marsh	No effect	0.1	2.0	0
Alkali rain pool	No effect	1.0	1.1	13.5
Riparian woodland	No effect	No effect	2	2
Cultivated lands	No effect	70	60	2,615
Pond	No effect	No effect	No effect	2
Total	**No effect**	**349.14**	**1,085.2**	**12,187.3**
Alternative D				
California annual grassland	600	178	790	4,910
Alkali grassland	30	100	230	3,698
Vernal pool	5.5	0.04	0.1	15.8
Great Valley iodine brush scrub	10	0	0	280
Freshwater marsh	No effect	0.1	2.0	0
Alkali rain pool	0.4	1.0	1.1	13.1
Riparian woodland	No effect	No effect	2	2
Cultivated lands	No effect	70	60	2,615
Pond	No effect	No effect	No effect	2
Total	**645.9**	**349.14**	**1085.2**	**11,536**

[a] Temporary effects include the effects associated with extraction facilities.

[b] Permanent effects include up to 40 acres of facilities in Phase 1. The total reflects conservative assumptions that all Phase 2 recharge bases would be constructed under the Alternative. Phase 2 recharge bases would only be constructed as required to augment Phase 1 recharge facilities. Acreages associated with construction of the Phase 2 recharge basins are apportioned across habitat types within a 1,300-acre area.

A summary of Proposed Action project elements located within water bodies and upland habitats are included in Table 3-13.

Table 3-13 Project Elements within and near Water Bodies and Uplands

Project Elements	U.S. Water Subject to CWA 404	Approximate Length/ Surface Area/Cut/Fill
Proposed Water Body Components		
Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection Upgrade (Section 8 Canal/Cottonwood Creek Connection)	Yes	250 lf cut
Gravelly Ford Canal Sedimentation Basin and Flow Regulation Area (Weir #1)	Yes	500 sf
Gravelly Ford Canal Flow Control Weir at Cottonwood Creek (Weir #2)	Yes	500 sf
Cottonwood Creek overflow improvements (rock slope protection)	Yes	350 lf
Reconditioning of existing canals and ditches (canal maintenance)	Yes	Excavation to previous shape
Reconditioning of existing canals and ditches (canal maintenance)	Yes	75 sf each
Planned Water Body Components		
Cottonwood Creek Lift Stations	Yes	500 sf each
Gravelly Ford Canal Section 21 Northern/Western Laterals	Yes	100 sf
Gravelly Ford Canal Section 22 Southern Lateral	Yes	100 sf
Other Components within and near Water Bodies		
24.2 Canal improvements	Yes	36,000 cy excavation; (1.75 mile expanded and 0.75 mile new)
Section 8 Canal upgrades/extensions	Yes	76,000 cy excavation; (1.75 mile expanded, 1.75 mile existing to pipe, and multiple new extensions)
Use of swales for recharge(1) (2)	No	No cut or fill. <6 acres vernal pool/alkali rain pool from use of swales (Alternative B) and <2 acres for Reduced Alternative B
55 acres of recharge basins in agricultural lands	No	55 acres
Recharge basins in grasslands	No	Varies
Recovery wells	No	<0.1 acre/well
Recovery pipelines and electrical facilities (3)	No	<1.5 ac vernal pool/alkali rain pools from corridors

Notes:
1 Vernal pools are located in swales and are subject to review under ESA Section 7 and CWA Section 404.
2 Swales not used for recharge under Alternative C. See Table 3-12 for vernal pool/alkali rain pool effects under each Alternative.
3 Alternatives B, Reduced Alternative B, C, and D are the same for recovery facilities because the layout does not change.
CWA = Clean Water Act; lf = linear feet; sf = square feet; cy = cubic yards.

The Proposed Action could result in both direct and indirect effects. Activities that could result in direct effects on sensitive habitats and sensitive species include:

- flooding swales on a seasonal basis;
- excavating areas to construct recharge basins and distribution canals/ditches;
- disposing of soil from excavation activities;
- drilling recovery wells and building pump plants;
- trenching to install the distribution and collection pipelines;

- blading of existing access roads (annually) and pesticide use;
- during operation of recharge basins, applying algicide or other chemicals if necessary to keep vegetation in check and minimize algae growth;
- compacting soils by traffic on and adjacent to construction access corridors and staging areas and by vehicle use of maintenance roads;
- potentially spilling toxic substances from vehicles during construction and operations and maintenance;
- creating noise during construction and maintenance; and
- disturbing bird nests.

The Proposed Action also may cause indirect effects. Indirect effects occur later in time or are farther removed in distance but must be predictable and reasonably certain to occur in order to be assessed. Potential mechanisms of indirect effects on sensitive habitats and sensitive species include:

- changes in hydrology, such as altered patterns of runoff or changes to the surface water retention pattern and capacity and elevation of the perched water table;
- erosion and sedimentation that result from grading and other activities that remove vegetation;
- water quality effects from contaminants such as road runoff or pesticides; and
- introduction of invasive nonnative species, including mosquitofish and bullfrog.

The activities described above can result in both permanent and temporary effects. Effects were characterized as permanent if they would result in the conversion of habitat to nonhabitat for the life of the Proposed Action. The extent of permanent and temporary effects on habitats at Madera Ranch was estimated by overlaying the outline of proposed recharge basins, canals/ditches, extraction wells, pipelines, and maintenance roads (proposed footprint) on the map of habitats. The footprint for the buried pipelines, maintenance roads, and canals/ditches is estimated to be a linear corridor 10 feet wide. The proposed footprint for the extraction wells is estimated to be 0.1 acre each.

Regularly traveled maintenance roads could remain all or partially unvegetated for the life of the Proposed Action as a result of disturbance and soil compaction. During construction activities, individual plants could be uprooted, buried, or crushed.

3.4.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative, Reclamation would not approve the banking of CVP water outside MID's service area, nor would Reclamation issue an MP-620 permit, a Mid-Pacific Region-specific permit for modifications to its distribution system. Reclamation's action would have no adverse effects on biological resources. The future conditions would continue to support agricultural activities; the type and extent of the activities is uncertain at this time. Future owners would be subject to comply with CESA and ESA and the effects may be evaluated by the County under CEQA if discretionary permits are needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect BIO-1: Temporary Disturbance of California Annual Grassland and Alkali Grassland during Construction Construction activities (e.g., traffic, laydown, work areas) could remove approximately 178 acres of California annual grassland and 100 acres of alkali grassland (Table 3-12 and Figure 3-5). California annual grassland and alkali grassland are resilient plant communities, as demonstrated in Sections 14, 15, 16, 17, 18, and 22 at Madera Ranch, where they have recovered from previous cultivation (Figure 3-5). Effect BIO-1 is not expected to cause long-term degradation and therefore would not be considered adverse.

Effect BIO-2: Permanent Removal of California Annual Grassland and Alkali Grassland Habitats during Construction Construction of the proposed recharge basins, canals/ditches, extraction wells, pipelines, and maintenance roads could permanently remove up to approximately 790 acres of California annual grassland and up to approximately 230 acres of alkali grassland habitats (Table 3-12 and Figure 3-5). Effect BIO-2 would be an adverse effect because it would substantially reduce the amount of this locally uncommon habitat. Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement would compensate for this loss of habitat.

Effect BIO-3: Loss or Disturbance of Iodine Bush Scrub or Sensitive Plant Species Habitat as a Result of Construction Iodine bush scrub habitat on Madera Ranch is limited to the northern half of Section 7 (Figure 3-5). Up to one well and a pipeline to deliver recovered groundwater back into MID's distribution system would be constructed in the northwest corner of the project area. Thus, activities associated with Effect BIO-3 could result in the loss or temporary disturbance of iodine bush scrub in Section 7. The effect would be considered adverse. Similarly, although previous botanical surveys indicated that state- and federally listed plants are not present, if there is a localized effect, it could be substantial to regional populations of iodine bush scrub. Therefore, Environmental Commitment BIO-3a: Avoid Effects on Iodine Brush Scrub and Environmental Commitment BIO-3b: Survey for Sensitive Plants are proposed.

Effect BIO-4: Potential for Construction-Related Mortality of Sensitive Vernal Pool Crustaceans Excavating, grading, trenching, soil movement, soil compaction, and removal of vernal pools, alkali rain pools, or artificial wetlands could result in direct adverse effects on vernal pool crustaceans (Impacts on wetlands are described in the Wetlands section). Trenching and soil movement could result in indirect adverse effects by altering suitable habitat, such as changing the hydrology of or increasing sedimentation in the pools (Table 3-12).

Vernal pool fairy shrimp, listed as threatened under the ESA, was identified in several pools during surveys at Madera Ranch. No other vernal pool crustaceans were found during those surveys, although suitable habitat may be present. Construction activities would avoid most of the naturally occurring vernal pools. Vernal pools previously were mapped in GF Canal, but these have been inundated for the past several years and are unlikely to function as vernal pools.

Effect BIO-4 could have an adverse effect on vernal pool fairy shrimp and substantially reduce the local distribution of sensitive biological resources occurring at Madera Ranch. This effect is considered adverse and would be minimized and compensated for with the implementation of Environmental Commitment BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal Pools and Alkali Rain Pools and Environmental Commitment BIO-2b: Create, Restore, or Preserve Vernal Pools.

Effect BIO-5: Potential for Operation- and Maintenance-Related Mortality of Sensitive Vernal Pool Crustaceans Operation and maintenance of MID facilities could result in direct effects on vernal pool crustaceans. Flooding swales on a seasonal basis could result in degradation of vernal pool habitat for vernal pools within the swales and major adverse effects on vernal pool crustaceans in these areas. Temporary rapid expansion of the existing pools from uncontrolled flows could move extant crustaceans and their eggs to peripheral areas where they could be subject to increased mortality from desiccation and/or predation during subsequent rapid pool-size decrease as the waters percolate into the subsurface. Other operational effects are also possible.

As described in the Public Health and Safety Section, if the swales pond water and mosquitoes become an issue with the Madera County Mosquito and Vector Control District (MCMAVCD), the abatement district may use mosquitofish to control mosquitoes. These fish also could prey on vernal pool species, should they survive prolonged inundation. However, the overall need for mosquitofish is expected to be low because water levels would fluctuate rapidly as water flows through the swales and generally would not persist after flows cease.

Furthermore, if swales are wet or moist year-round, they could become a dispersal corridor for bullfrogs. Bullfrogs could prey on vernal pool species. However, swales are not expected to be wet year-round and periodic drying of the swales would inhibit the establishment of bullfrogs in the interior of the property. Maintenance of new permanent facilities will take place more than 250 feet from existing vernal pools, but adverse effects potentially could occur.

Effect BIO-5 is adverse because it could affect fairy shrimp occurring at Madera Ranch. This effect would be minimized and compensated for with the implementation of Environmental Commitment BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal Pools and Alkali Rain Pools and Environmental Commitment BIO-2b: Create, Restore, or Preserve Vernal Pools.

Effect BIO-6: Potential for Construction-Related Mortality of San Joaquin Tiger Beetle Construction activities and modification of annual grassland and alkali grassland, slickspots in particular, could have an adverse effect on the San Joaquin tiger beetle. The San Joaquin tiger beetle is not a federally or state-listed species but is sufficiently rare to be of concern. Most habitats on Madera Ranch are suitable for this species, although alkali scalds and vernal pools are most suitable because these habitat types provide foraging opportunities.

Some individual beetles could be killed from direct effects during construction activities and indirect effects caused by habitat modification. Excavating, grading, trenching, soil movement, soil compaction, and vehicle traffic in the Madera Ranch vicinity could result in direct effects on the species. Adults and larval beetles could be trapped inside their burrows during grading or trenching, crushed on the ground by construction-related vehicles, or disturbed to the point that they abandon their foraging areas. Construction activities near occupied habitats also could result in indirect effects. Trenching and soil movement could result in indirect effects such as altering the hydrology and soil microenvironment, making it unsuitable for egg deposition or larva habitation. Construction of the recharge basins could remove up to approximately 230 acres of alkali grassland containing slickspot habitat (Table 3-12).

Potential habitat for San Joaquin tiger beetle is widely distributed, and construction would disturb less than 10% of its potential habitat on Madera Ranch. Therefore, Effect BIO-6 is considered adverse, but it does not represent a substantial reduction in the local or regional distribution of San Joaquin tiger beetles.

Effect BIO-7: Potential for Operation- and Maintenance-Related Mortality of San Joaquin Tiger Beetle The San Joaquin tiger beetle could be affected by operations and maintenance of MID facilities. Operating and maintaining the recharge basins and extraction facilities and maintaining the banks of the conveyance canals could have direct adverse effects on this species if they use these areas. Adults and larval beetles could die from contact with herbicides, be trapped inside their burrows during disking or filling of burrows, be crushed by vehicles, or be disturbed by these activities to the point that they abandon their foraging areas. Flooding swales on a seasonal basis also could cause mortality of tiger beetles and larvae.

Potential habitat for San Joaquin tiger beetle is widely distributed, and operations would disturb less than 10% of its potential habitat on Madera Ranch. Therefore, Effect BIO-7 is not considered adverse because it does not represent a substantial reduction in the local or regional distribution of San Joaquin tiger beetles.

Effect BIO-8: Potential for Construction-Related Mortality of California Tiger Salamander Construction and modification, including direct and indirect effects on naturally occurring vernal pools, alkali rain pools, wetlands in GF Canal, annual grassland, and alkali grassland could have major adverse effects on California tiger salamander if this species is present on Madera Ranch (Impacts on wetlands are described in a separate section on Wetlands).

The California tiger salamander is federally listed as threatened and is a candidate for listing under CESA. Vernal and alkali rain pools are potential breeding habitat for this species, and upland areas within 1.25 miles of a wetland are potential nonbreeding habitat. Madera Ranch has suitable habitat for this species, and it is within the historical distribution range, but no evidence of California tiger salamanders was found during reconnaissance surveys conducted for amphibians while surveying for vernal pool crustaceans.

Excavating, grading, trenching, soil movement, soil compaction, and removing vernal pools and adjacent nonbreeding habitat could result in direct effects on this species. Tiger salamanders could be trapped inside their estivation or shelter burrows, crushed by construction vehicles, or displaced to adjacent areas where they could be subject to increased exposure, food shortages, and predation. Grading, trenching, and soil movement could alter the hydrology of the habitat and compact available animal burrows suitable for shelter and estivation, causing additional indirect adverse effects on the species.

If tiger salamanders are present, Effect BIO-8 would have an adverse effect on a species that is listed as threatened under the ESA and is a candidate for listing under CESA and could substantially reduce the local distribution of sensitive biological resources occurring at Madera Ranch. This effect would be minimized and compensated for with the implementation of Environmental Commitments BIO-1: Establish a Grasslands Conservation Easement; BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal Pools and Alkali Rain Pools; BIO-2b: Create, Restore, or Preserve Vernal Pools; BIO-4a: Preconstruction Surveys for California Tiger Salamander; BIO-4b: Restrict Construction Activity in Suitable Aquatic and Upland Habitat for California Tiger Salamander to the Dry Season (April 1–November 1); and BIO-4c: Fence the Construction Zone and Implement Erosion Control Measures in Areas Where Suitable Aquatic Habitat for California Tiger Salamander Is Present.

Effect BIO-9: Potential for Operation- and Maintenance-Related Mortality of California Tiger Salamander Operation and maintenance of MID facilities could result in direct effects on California tiger salamander if this species is found to occur in vernal pools that would be near these activities. Flooding natural swales on a seasonal basis could result in beneficial or adverse effects on this species. Expanded pool size and duration could benefit breeding tiger salamanders by increasing the area and time available for breeding. However, rapid pulsing of water input and percolation loss following the initiation of breeding could result in the movement of adults, larvae, and eggs to areas beyond the traditional boundaries of the vernal pool and result in increased loss from desiccation and/or predation. Other operational effects are also possible. As described in the Public Health and Safety Section, if the swales pond water and mosquitoes become an issue with the MCMAVCD, the abatement district may use mosquitofish to control mosquitoes. These fish could also prey on California tiger salamander larvae. However, the overall need for mosquitofish is expected to be low because water levels would fluctuate rapidly as water flows through the swales and generally would not persist after flows cease. Furthermore, if swales are wet or moist year-round, they could become a dispersal corridor for bullfrogs. Bullfrogs could prey on California tiger salamander. However, swales are not expected to be wet year-round, and periodic drying of the swales would inhibit the establishment of bullfrogs in the interior of the property.

If California tiger salamanders are present, an adverse effect could occur on a species that is listed as threatened under the ESA and could substantially reduce the local distribution of sensitive biological resources occurring at Madera Ranch. This effect would be minimized and compensated for with the implementation of Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement; Environmental Commitment BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal Pools and Alkali Rain Pools; and Environmental Commitment BIO-2b: Create, Restore, or Preserve Vernal Pools.

Effect BIO-10: Potential for Construction- and/or Operation- and Maintenance-Related Mortality of Western Spadefoot Toad Construction and operations/maintenance activities potentially could result in direct or indirect loss of western spadefoot toads currently known to occupy vernal pools on Madera Ranch. The western spadefoot toad is designated as a species of special concern by DFG.

Western spadefoot toad tadpoles were observed in GF Canal in 2000 (Figure 3-4). Vernal and alkali rain pools are potential breeding and estivation habitat for this species. Other operational effects as describe above related to mosquitofish and bullfrogs also possibly could occur.

Although western spadefoot toads are widely distributed throughout California, suitable habitat at Madera Ranch is limited to vernal pools and alkali rain pools. Therefore, Effect BIO-10 is potentially moderately adverse because it could substantially reduce the local distribution of western spadefoot toads. This effect would be minimized and compensated for with the implementation of Environmental Commitment BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal Pools and Alkali Rain Pools and Environmental Commitment BIO-2b: Create, Restore, or Preserve Vernal Pools.

Effect BIO-11: Potential for Construction- and/or Operation- and Maintenance-Related Effects on Blunt-Nosed Leopard Lizard Construction activities and modification of annual grassland and alkali grassland habitat could have an adverse effect on blunt-nosed leopard lizard habitat. The blunt-nosed leopard lizard is listed as endangered under CESA and ESA and as a fully protected species under the California Fish and Game Code. Historical records indicate the presence of blunt-nosed leopard lizard in the vicinity of Madera Ranch and on Madera Ranch, and a few individuals were recently confirmed on site. The approximately 4,044 acres of alkali grassland habitat and high kangaroo rat burrow density make much of Madera Ranch suitable for blunt-nosed leopard lizard (Figure 3-5).

Construction activities, including excavating, grading, trenching, soil movement, and noise and disturbance from vehicle traffic, could result in harm to and harassment of the species. Operational activities, including banking water in the swales, also could result in harm to and harassment of this species. Direct mortality is not authorized under California Fish and Game Code. Therefore, Effect BIO-11 is considered an adverse effect because direct mortality of this species must be avoided to comply with state law and because any effect could be a substantial adverse effect on the species or a substantial reduction in the local or regional distribution of blunt-nosed leopard lizard.

In the event Phase 2 is constructed, up to 230 acres of alkali grassland habitat and 790 acres of annual grassland could be permanently affected. The extent of this effect on the species depends on the presence and abundance of the species in the construction area and the species' ability to persist in the area post-construction. If the species is present, the effects could be substantial. However, initial surveys indicate densities are likely to be low and these areas have previously been cultivated. To offset these potential habitat effects, MID would establish a conservation easement equivalent to the size of the disturbance area.

To minimize and mitigate the potential effect of Alternative B, MID would implement Environmental Commitments BIO-1: Establish a Grasslands Conservation Easement and BIO-5: Pre-Activity Surveys for Blunt-Nosed Leopard Lizard.

Effect BIO-12: Potential for Construction- and/or Operation- and Maintenance-Related Mortality of California Horned Lizard Construction and modifying grassland and alkali grassland habitat could have an adverse effect on the California horned lizard, which is listed as a California species of special concern.

Constructing facilities could result in converting existing grassland habitat suitable for the species. Direct mortality could result from excavating, grading, trenching, and soil movement. Individuals could be trapped inside burrows during construction; crushed by construction vehicles; or displaced to adjacent areas where they could be subject to increased exposure, food shortages, and predation. Flooding swales on a seasonal basis also could result in loss of some individuals. The level of loss from all activities associated with Alternative B, however, is anticipated to be low, if loss occurs at all, because no California horned lizards were observed during transect surveys.

Potential habitat for California horned lizards is widely distributed in California, specifically in Madera County and on Madera Ranch. Therefore, Effect BIO-12 is not considered adverse because it does not represent a substantial reduction in the local or regional distribution of California horned lizards.

Effect BIO-13: Potential for Construction- and/or Operation- and Maintenance-Related Mortality of Silvery Legless Lizard Construction and modifying grassland and alkali grassland habitat could have an adverse effect on the silvery legless lizard, which is considered sufficiently rare and/or vulnerable by the scientific community to be of concern. Constructing facilities could result in converting existing grassland habitat suitable for the species. Direct mortality could result from excavating, grading, trenching, and soil movement. Individuals could be trapped inside burrows during construction; crushed by construction vehicles; or displaced to adjacent areas where they could be subject to increased exposure, food shortages, and predation. Flooding swales on a seasonal basis also could result in the loss of some individuals. The level of loss from all activities associated with Alternative B, however, is anticipated to be low, if loss occurs at all.

Effect BIO-13 would not be considered adverse because it would not substantially reduce the local or regional distribution of this species.

Effect BIO-14: Potential for Operation- and Maintenance-Related Harm and Harassment of Giant Garter Snake Alternative B would have no effect on this species on Madera Ranch because aquatic habitat does not pond for a sufficient duration to support a prey base for this species. Focused surveys for this species by Dr. Sean Barry confirmed that the habitat was unsuitable and the species was not present. Similarly, canals within the MWMA are also unsuitable for giant garter snake because of extended periods of dryness, seasonal fluctuation of water, and lack of consistent prey base. Long-term habitat conditions on Madera Ranch are not expected to improve for giant garter snake because of the seasonal nature of MID's operations. If DFG uses the bank to store water for management activities at MWMA, the activities would only be those that are in the current management plan, which is in compliance with Federal ESA and CESA. Therefore, project operations and maintenance would have no effect on this species.

Effect BIO-15: Potential for Construction-Related Disturbance of Nesting Swainson's Hawk and White-Tailed Kite Construction of facilities has the potential to directly affect nesting Swainson's hawk and white-tailed kite. The Swainson's hawk is designated federal bird of conservation concern and the white-tailed kite is a fully protected species under the California Fish and Game Code. Both species have been documented on Madera Ranch. Suitable foraging habitat is present throughout the area, but nesting habitat is limited because few trees are present. Noise associated with excavating, grading, trenching, and drilling at the Madera Ranch site could result in displacement of adult birds from active nests, resulting in the loss of eggs or nestlings. Conversion of cultivated lands to recharge basins also could result in loss of potential foraging habitat for these species – particularly Swainson's hawk – requiring individuals to fly farther to obtain food. The energy costs required to obtain food could affect annual productivity of nesting pairs in the area.

Alternative B is not expected to have direct effects on individuals of these species. The indirect effect of conversion of cultivated lands is minor because approximately 60 acres of farmland would be converted to nonagricultural use and the surrounding areas are dominated by agricultural lands. The potential indirect effect of construction-related noise on active nests (Effect BIO-15) would be adverse because it could substantially reduce the local distribution of sensitive biological resources. This effect would be minimized with the implementation of Environmental Commitment BIO-6: Preconstruction Surveys and Avoidance Activities for Raptors.

Effect BIO-16: Potential Loss of Foraging Area for Greater Sandhill Crane, Golden Eagle, Ferruginous Hawk, Prairie Falcon, Merlin, Mountain Plover, Long-Billed Curlew, and Short-Eared Owl Construction and modification of annual grassland and alkali grassland could result in loss of potential foraging habitat for these species (Table 3-11). Greater sandhill crane is state listed as threatened. Golden eagle, ferruginous hawk, prairie falcon, merlin, mountain plover, long-billed curlew, and short-eared owl are species of concern for the USFWS or DFG. The golden eagle also is a fully protected species under the California Fish and Game Code and the BGEPA. These species use Madera Ranch during the nonbreeding season for foraging and resting; none of these species is likely to use the area for breeding.

Construction of the facilities could result in the use and conversion of approximately 5–10% of the grassland habitat at Madera Ranch that could be used for resting and foraging (Table 3-11). However, these species are highly mobile and forage in a variety of sites throughout the Central Valley, and no direct mortality is anticipated from the indirect effect of losing available prey as a result of this habitat conversion, and no breeding habitat would be lost. Therefore, Effect BIO-16 is not considered adverse because it would not substantially reduce the local or regional distribution of these species.

Effect BIO-17: Potential for Construction-Related Mortality of Western Burrowing Owl Western burrowing owl could be crushed during grading and soil movement activities proposed. The Western Burrowing Owl is designated as a federal species of special concern by USFWS. The Western Burrowing Owl has been documented on Madera Ranch. Western Burrowing Owls nest in burrows, with annual and alkali grasslands providing suitable foraging and nesting habitat.

Excavating, grading, trenching, soil movement, and soil compaction at the Madera Ranch site could result in direct effects on burrowing owls. Individuals could be trapped inside their burrows during grading or trenching, crushed on the ground by construction-related vehicles, or disturbed to the point that they abandon their burrows. Burrowing owls displaced to adjacent areas ultimately may die as a result of starvation, exposure, or predation. Construction activities near occupied habitats also could result in indirect effects. Construction of the recharge basins could remove vegetation and habitat for various prey species. A decline in forage species availability could be an indirect effect on the burrowing owls.

The potential effect of construction on this species could be adverse because it could have a substantial local adverse effect on a sensitive species and substantially reduce the local distribution of sensitive biological resources. This effect would be minimized with the implementation of Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement and BIO-7: Preconstruction Surveys for Western Burrowing Owl.

Effect BIO-18: Potential for Operation-Related Mortality of Western Burrowing Owl
Western burrowing owls, their eggs, and their fledglings nest in burrows. Flooding swales on a seasonal basis would not be expected to adversely affect the active nests of these species because flooding typically would begin well before the start of the breeding season (mid-March) and end before the peak of the breeding season (mid-April). Western Burrowing Owls also prefer nest locations that are not at the low-point of swales to minimize predation and dry to increase nest success. The owls on site are also habituated to ranch vehicles and farm equipment traveling around the site, and most facilities would need to be accessed in the summer, post-breeding season. Some loss of burrowing owl habitat would occur. However, lost burrows would be replaced.

Effect BIO-19: Potential for Construction-Related Harm to Loggerhead Shrike The Loggerhead shrike is a federal bird of conservation concern. Loggerhead shrikes have been documented throughout the Madera Ranch area. Annual and alkali grasslands provide suitable foraging habitat, but nesting habitat is limited to portions of GF Canal and cultivated portions of the property (Figure 3-4).

Construction activities and modification of grassland and alkali grassland habitat could have an adverse effect on loggerhead shrikes, and Alternative B would result in the loss of approximately 5–10% of their foraging habitat (Table 3-12).

Noise associated with excavating, grading, trenching, and vehicle traffic at the Madera Ranch site could result in displacement of loggerhead shrikes from active nests, resulting in the loss of eggs or nestlings. Individual, nonbreeding birds also may respond to the disturbance of construction activities by leaving the area.

The potential loss of foraging habitat and indirect effect of construction-related noise on active nests would be adverse because it could substantially reduce the local distribution of sensitive biological resources. This effect would be minimized and compensated for with the implementation of Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement.

Effect BIO-20: Potential for Construction-Related Foraging Habitat Loss for Tricolored Blackbird Converting agricultural land could have an adverse effect on Tricolored Blackbirds. The Tricolored Blackbird is designated as a state species of special concern by DFG and as a species of federal special concern by USFWS. Madera Ranch area is in the historical range of the tricolored blackbird, and Madera Ranch contains suitable habitat. Tricolored blackbirds occur infrequently on Madera Ranch, foraging on the grasslands and agricultural lands. No mortality is anticipated from direct or indirect effects of the construction activities associated with Alternative B. Crop production would continue on agricultural lands still under the ownership of MID. Effect BIO-20 would not be considered adverse because of the nomadic nature of breeding in this species and the availability of other crop breeding areas at or near Madera Ranch.

Effect BIO-21: Potential for Effects on San Joaquin Kit Fox Vehicle traffic, excavating, grading, trenching, soil movement, and soil compaction could result in direct effects on this species, if present. San Joaquin kit foxes, if present, potentially could be trapped inside their den burrows, crushed by construction vehicles, or displaced to adjacent areas where they could be subject to increased exposure, food shortages, and predation. Additionally, noise and ground vibration from intermittent well operation may mask important natural sounds used by kit foxes to detect prey and avoid predators.

Operational effects, including vegetation changes resulting from seasonal inundation of swales, also have the potential to affect this species. These operational effects are unlikely to adversely affect the kit fox because of their mobility and home range size. Foraging is unlikely to be affected because prey populations are expected to be the same post-project. Other types of vehicle traffic, soil movement, and compaction effects associated with maintenance may occur intermittently, in small areas where repairs are needed. These effects may occur along the same corridor in which the facility was initially installed. Overall, because of the abundance of the grasslands and the species' habitat requirements, these effects are unlikely to adversely affect the potential for San Joaquin kit fox to persist on Madera Ranch, should they be present.

In the event Phase 2 is constructed, up to 230 acres of alkali grassland habitat and 790 acres of annual grassland could be permanently affected. The extent of this effect on the species depends on the presence and abundance of the species in the construction area and the species' ability to persist in the area post-construction. If the species is present, the localized direct effects could be substantial if the species is not avoided. However, initial surveys indicate densities are likely to be low and these areas have previously been cultivated.

This effect is considered potentially moderate and would be minimized with the implementation of Environmental Commitments BIO-1: Establish a Grasslands Conservation Easement and BIO-8: Preconstruction Surveys for San Joaquin Kit Fox.

Effect BIO-22: Potential for Effects on Fresno Kangaroo Rat Excavating, grading, trenching, soil movement, soil compaction, and removing grassland habitat could adversely affect the Fresno kangaroo rat, if present. Habitat losses in Phase 1 include approximately 280 acres of temporary effects and 40 acres of permanent effects. Individuals could be trapped inside their burrows, crushed by construction vehicles, or displaced to adjacent areas where they could be subject to increased exposure, food shortages, and predation. Trenches left open during the night could trap Fresno kangaroo rats that might be active within the construction area. Operational effects also have the potential to result in effects on this species. Use of the swales could result in a new mosaic of habitats, including new plant species. The overall implications of this change in habitat conditions, and thereby the Fresno kangaroo rat, are difficult to predict. The plant species composition is likely to change because the wetter conditions may favor the growth of wetland species or upland species that are less drought-tolerant. This process has been observed on Madera Ranch, as swales with irrigation runoff discharged into them have experienced an increase in nonnative weedy plants. In Section 7, Great Valley iodine bush scrub habitat (10 acres) could benefit from a rising water table. Approximately 710 acres of annual grasslands, some with friable soils, are in the swales. Foraging is unlikely to be affected because seed production is expected to be similar following implementation of Alternative B. Dispersal is unlikely to be affected because the swales historically have flooded, and because these areas still would be usable for most of the year for the species life history requirement (including movement, food storage, and sand-bathing). Overall, because of the abundance of the grasslands and the species habitat requirements, localized vegetation changes are unlikely to adversely affect the Fresno kangaroo rat populations on Madera Ranch, should they be present.

While the potential for Fresno kangaroo rat to be present is small based on previous surveys, acoustic degradation of habitat attributable to noise and ground vibration from well operation potentially could disturb them in the vicinity of the pumps. Pump noise also may mask sounds of approaching predators, thereby increasing the potential of predation for this species. However, very little is known about nature of these potential impacts, nor the adaptive capacity of kangaroo rats to accommodate to such noise. However, kangaroo rats are especially sensitive to low-frequency sounds. Work on the desert kangaroo rat and other dune vertebrates have shown that off-road vehicle sound levels have a serious impact on hearing acuity (Brattstrom and Bondello 1983 cited in Goldingay et al. 1997). The pumps would operate intermittently and only during periods of water extraction. To some degree, the operation of construction equipment could cause these same effects.

In the event Phase 2 is constructed, up to 230 acres of alkali grassland habitat and 790 acres of annual grassland could be permanently affected. The extent of this effect on the species depends on the presence and abundance of the species in the construction area and the species' ability to persist in the area post-construction. If the species is present, the localized direct effects could be substantial if the species is not avoided. Despite possible low densities, Effect BIO-22 is considered adverse because, if Fresno kangaroo rat is present, it could substantially reduce the local or regional distribution of this species. This effect would be minimized with the implementation of Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement and Environmental Commitment BIO-9: Conduct Pre-Activity Surveys for Fresno Kangaroo Rat.

Effect BIO-23: Potential for Mortality of San Joaquin Pocket Mouse Construction and modifying annual grassland and alkali grassland could have an adverse effect on San Joaquin pocket mouse. Annual and alkali grasslands provide suitable habitat for this species, and San Joaquin pocket mice were captured throughout Madera Ranch during small mammal trapping. Excavating, grading, trenching, soil movement, soil compaction, and vehicle traffic at the Madera Ranch site could result in direct effects on pocket mice. Individuals could be trapped inside their burrows during grading or trenching, crushed on the ground by construction-related vehicles, or disturbed to the point that they abandon their burrows. Construction of recharge basins could modify and remove forage vegetation and habitat for burrows. Flooding swales on a seasonal basis also could displace individuals from their burrows, making them vulnerable to exposure and predation. The San Joaquin pocket mouse is known to enter torpor (a dormancy period) during colder weather. If flooding occurred during these colder time periods (such as early spring), individuals could be at risk of drowning in their burrows.

However, because there are successful breeding individuals on Madera Ranch and because suitable habitat will continue to be abundant on site, localized effects are not expected to inhibit future breeding success. Therefore, Effect BIO-23 is not adverse because it would not substantially reduce in the local or regional distribution of these species.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales will be used in order to minimize effects to vernal pools, and a reduced number of ponds will be constructed. As with Alternative B it would complete the water bank in two phases. Phase 1 would involve constructing necessary delivery infrastructure improvements (except for the Section 8 canal southwest extension), using select natural swales for recharge (550 acres versus 700 acres as proposed under Alternative B), and installing approximately five soil berms to direct recharge flows. Phase 2 would involve constructing a limited number of recharge basins (323 acres versus up to 1,000 acres under Alternative B) and facilities for recovery of banked water.

Reduced Alternative B would result in nearly identical effects on biological resources as those identified under Alternative B, with the exception of the following effects:

- Effect BIO-4: Potential for Construction-Related Mortality of Sensitive Vernal Pool Crustaceans
- Effect BIO-5: Potential for Operation- and Maintenance-Related Mortality of Sensitive Vernal Pool Crustaceans
- Effect BIO-6: Potential for Construction-Related Mortality of San Joaquin Tiger Beetle
- Effect BIO-9: Potential for Operation- and Maintenance-Related Mortality of California Tiger Salamander
- Effect BIO-10: Potential for Construction- and/or Operation- and Maintenance-Related Mortality of Western Spadefoot Toad

The reduced footprint of recharge basins and number of swales proposed under Reduced Alternative B would reduce the potential for Effects BIO-4, BIO-5, BIO-6, BIO-9 and BIO-10.

The Environmental Commitments identified for Alternative B associated with effects on biological resources would be appropriate and applicable under Reduced Alternative B.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the exception that recharge is achieved using engineered recharge basins in lieu of the natural swales that occur on the site. Thus, engineered basins would be built in Phase 1 instead of using the swales in Phase 1 under Alternative B. However, the expected footprint of recharge basins under Alternative B would be identical to the maximum build-out of Phase 2 of Alternative B and would result in nearly identical effects on biological resources (Effects BIO-1, BIO-2, BIO-4, BIO-6 through BIO-10, BIO-12 through BIO-21, and BIO-23).

Effect BIO-3: Loss or Disturbance of Iodine Brush Scrub or Sensitive Plant Species Habitat and Effect BIO-5: Potential for Operation- and Maintenance-Related Mortality of Sensitive Vernal Pool Crustaceans are lower under this alternative because the swales are not used for recharge and fewer vernal pools and alkali rain pools, including plant species habitat (habitat for Greene's tuctoria), would be inundated from banking activities.

In contrast, Effect BIO-11: Potential for Construction- and Operation- and Maintenance-Related Effects on Blunt-Nosed Leopard Lizard; Effect BIO-21: Potential Effects on San Joaquin Kit Fox; and Effect BIO-22: Potential for Effects on Fresno kangaroo Rat would be higher, as grassland habitat would be guaranteed to be permanently affected by the creation of permanent recharge basins (under Alternative B the overall need and quantity of ponds likely will be lower than the maximum 1,000 acres possible). The Environmental Commitments identified for Alternative B associated with these effects would be appropriate and applicable under Alternative C.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B. The majority of the swales proposed under Alternative C would also be used (less approximately 100 acres), and the expected footprint of recharge basins under Phase 2 of Alternative D would be nearly identical to Phase 2 of Alternative B. Alternative D would result in nearly identical effects on biological resources as Alternative B, including Effects BIO-1 through BIO-23. The Environmental Commitments associated with these effects are still appropriate and applicable. Off-site improvements on GF Canal would occur in agricultural lands along the existing GF Canal. However, two additional effects were identified for this alternative (Effects BIO-24 and BIO-25 described below).

Effect BIO 24: Potential Mortality of Sensitive Species during Construction The off-ranch GF Canal alignment has not been surveyed for sensitive wildlife species. However, aerial photos and DWR land-cover review indicate that the majority of the alignment of the canal, more than 95%, is located in intensive agricultural lands and is unsuitable for many sensitive species.

However, construction of the checkdams, culvert crossings, and other facilities has the potential to adversely affect local individual species should suitable habitat be present. The potential effect of construction on sensitive species could be adverse because it could have a substantial local effect on a sensitive species and substantially reduce the local distribution of sensitive biological resources should they be present. This effect would be minimized with the implementation of Environmental Commitment BIO-10: Conduct Preconstruction Surveys for Sensitive Species along the Off-Ranch Portion of Gravelly Ford Canal.

Effect BIO-25: Potential for Entrainment of Anadromous Fish If Restored to the San Joaquin River When the San Joaquin River Restoration Program (SJRRP) proceeds and anadromous fish are restored to the San Joaquin River, Alternative D potentially could result in the entrainment of salmon and steelhead trout into the GF Canal. While these species currently are not present because of downstream barriers and the lack of suitable habitat, future restoration efforts contemplate the reintroduction of these species to the San Joaquin River. The potential effect of operation on anadromous species could be adverse because it could interfere substantially with the movement of any migratory fish. This effect would be minimized with the implementation of Environmental Commitment BIO-11: Implement Protective Measures for Anadromous Fish.

Cumulative Effects

Effect BIO-26: Result in a Cumulative Loss of Grassland Alternative D could potentially result in the loss or conversion of up to 700 acres of annual and alkali grassland habitat in recharge swales and up to 1,000 acres in recharge basins, which could contribute to the historical cumulative habitat loss. Substantial areas of Madera County have been converted to other uses, including agriculture and urban development, and this trend is expected to continue.

Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement would help reduce this effect; MID's proposed grasslands conservation easement at Madera Ranch would preserve in perpetuity an area of habitat equivalent in size to the area subject to long-term degradation or permanent displacement (1:1 ratio of acres conserved to acres lost). To compensate for the potential incremental cumulative effect of Alternative B, the preservation ratio will be increased to 1.2:1. This compensation would contribute to reduction of the projected future cumulative loss of this habitat type in western Madera County.

Effect BIO-27: Result in a Cumulative Loss of Habitat for Endangered Species Given the likely low density of most federally listed species on the property, the conservation measures proposed as part of Alternative B, the continued operation of the majority of the property in open space, and the mitigation lands that would be provided, vernal pool fairy shrimp, California tiger salamander, San Joaquin kit fox, blunt-nosed leopard lizard, and Fresno kangaroo rat are not anticipated to be irreparably harmed by the approval of Alternative B. However, there remains an adverse cumulative effect on these species because of the overall loss of their habitats throughout the Central Valley.

As both Alternatives C and D are similar in scope and effect to Alternative B, it is anticipated that Alternative C or D also would contribute to cumulative impacts on biological resources. Alternative B would contribute to cumulative impacts on grassland and biological resources dependent on grassland. The cumulative effects on grasslands are expected to be higher under Alternative C or D than under Alternative B because fewer ponds likely would be constructed, though the cumulative effects on vernal pools are expected to be lower because the swales would not be used for banking. Reduced Alternative B would have less cumulative impacts than Alternative B. The use of GF Canal under Alternative D is expected to result in a cumulative benefit to migratory fish because of increasing water supply reliability and storage and developing a water bank that facilitates instream flows.

3.5 Cultural Resources

The Proposed Project is considered a federal undertaking because Reclamation will be involved in project permitting. As a federal undertaking, the endeavor is subject to the provisions of Section 106 of the NHPA. The Section 106 process is a consultation process that involves the State Historic Preservation Office (SHPO) throughout; the process also calls for including Native American Tribes and interested members of the public, as appropriate, throughout the process.

Criteria for Determining Significance of a Resource

Section 106 requires federal agencies to consider the effects of their actions on properties that may be eligible for listing or are listed in the National Register of Historic Places (NRHP). To determine whether an undertaking could affect NRHP eligible properties, cultural resources (including archeological, historical, and architectural properties) must be inventoried and evaluated for the NRHP. To qualify for listing in the NRHP, a property must be at least 50 years old or, if fewer than 50 years old, be of exceptional historic significance. It must represent a significant theme or pattern in history, architecture, archaeology, engineering, or culture at the local, state, or national level. The criteria for evaluating the eligibility of cultural resources for listing in the NRHP are found in 36 CFR Part 60.4. A property must meet at least one of the following criteria:

1. is associated with events that have made a significant contribution to the broad patterns of our history; or
2. is associated with the lives of persons significant in our past; or
3. embodies the distinctive characteristics of a type, period or method of construction, or represents the work of a master, or possesses high artistic value, or represents a significant and distinguishable entity whose components may lack individual distinction; or
4. has yielded, or may be likely to yield, information important in prehistory or history.

In addition to meeting the significance criteria, potentially historic properties must possess integrity to be considered eligible for listing in the NRHP. Integrity refers to a property’s ability to convey its historic significance. Integrity is a quality that applies to historic resources in seven specific ways: location, design, setting, materials, workmanship, feeling, and association. A resource must possess two, and usually more, of these kinds of integrity, depending on the context and the reasons the property is significant.

3.5.1 Affected Environment

As a result of prefield research, historical research, the 2000 survey, 2002 survey, 2005 survey, and the 2009 survey, 16 cultural resources were identified within the Area of Potential Effect (APE) and evaluated for NRHP significance. These cultural resources are presented in Table 3-14. A detailed description and significance evaluation of these resources previously have been documented (Jones & Stokes 2002) and more recently have been documented (ICF Jones & Stokes 2009). None of these cultural resources appears to meet the significance criteria for NRHP listing. Reclamation requested SHPO concurrence on a finding of no historic properties affected. SHPO agreed with Reclamation's findings on August 31, 2009, and concurrence was received August 31, 2009 (Appendix E). However, since that time, a number of additional activities have been proposed which require expanding the APE. These activities include the proposed widening of the Section 8 Canal by 5 feet to accommodate additional water capacity; the addition of the southwest corner of Section 11 and the northern portion of Section 4 and 5 as a vernal pool areas; the proposed construction site of the Cottonwood Creek weir in Section 28; and the proposed construction site of the Gravelly Ford and Cottonwood Creek weir near Avenue 7 in Section 27. These areas and activities were not included in the original SHPO consultation package. Additional site surveys of this area were conducted on March 7-8, 2011 and no previously unknown cultural resources were identified. An updated memorandum (Appendix F) was prepared by consulting archaeologists.

Table 3-14 Cultural Resource Sites Identified at Madera Ranch

Primary Number or Trinomial	Temporary Site Number	Description
P-20-2402	JSA-Cultural-2	GF Canal
P-20-2385	JSA-Cultural-6	Road 17 segment
P-20-2386	JSA-Cultural-7	Historic road
P-20-2400	JSA-Cultural-8	Levee and associated ditches
P-20-2389	N/A	Concrete Footings
P-20-2390	JSA-Cultural-21	Historic road
CA-Mad-2309-H	JSA-Cultural-22	Water pumping location and access road
P-20-2393	JSA-Cultural-A-1	Irrigation ditch
P-20-2394	JSA-Cultural-B-1	Levee and associated ditches
CA-Mad-2310-H	JSA-Cultural-B-2	Water pumping location
P-20-2398	JSA-Cultural-B-6	Concrete ditch
P-20-2399	JSA-Cultural-B-7	Dry pond
P-20-2389	JSA-Cultural-B-18	Concrete footings
Main No. 1 Canal		Irrigation canal
Main No. 2 Canal		Irrigation canal
Section 8 Canal		Irrigation canal
24.2 Canal		Irrigation canal

A concise summary of regional prehistoric, ethnographic, and historic backgrounds is presented below. A detailed discussion of the regional setting for cultural resources previously has been documented in *Draft Cultural Resources Inventory* and Evaluation Report for the Proposed Madera Water Bank, Madera County, California (Jones & Stokes 2002) and in *Cultural Resources Inventory and Evaluation for the Madera Irrigation District Water Supply Enhancement Project, Madera County, California* (ICF Jones & Stokes 2009).

Prehistory

The Madera Ranch vicinity lies in the San Joaquin Valley cultural region (Moratto 1984). This region comprises the following four complexes, which describe specific cultural traits within a given time period:

- the Positas Complex,
- the Pacheco Complex,
- the Gonzaga Complex, and
- the Panoche Complex.

The Positas Complex (3300–2600 BC) is characterized by small, shaped mortars; short, cylindrical pestles; millingstones; perforated flat cobbles; and spire-lopped *Olivella* beads.

The Pacheco Complex (2600 BC–AD 300) comprises two phases: A and B. Phase B (2600–1600 BC) is characterized by foliated bifaces; rectangular *Haliotis* ornaments; and thick, rectangular *Olivella* beads. Phase A (1600 BC–AD 300) is represented by more varied types of shell beads. *Olivella* beads of spire-ground, modified saddle, saucer, and split-drilled types are present, as are *Haliotis* disc beads and ornaments. Other artifacts characteristic of this phase include perforated canine teeth; bone awls, whistles, and grass saws; large-stemmed and side-notched points; and an abundance of millingstones, mortars, and pestles (Moratto 1984; Olsen and Payen 1969).

The Gonzaga Complex (AD 300–1000) is characterized by burials in which the bodies of the deceased are either extended or flexed. This complex also is characterized by bowl mortars and shaped pestles; squared- and tapered-stem projectile points; few bone awls and grass saws; and a shell industry composed of distinctive *Haliotis* ornaments and rectangular, split-punched, and oval *Olivella* beads.

The Panoche Complex (AD 1500–European contact) is characterized by the presence of few millingstones and varied mortars and pestles; small side-notched arrow points; clamshell disc beads; *Haliotis* epidermis disc beads; *Olivella* lipped, side-ground, and rough disc beads; and bone awls, whistles, saws, and tubes. Flexed burials and primary and secondary cremations are found (Moratto 1984; Olsen and Payen 1969).

Ethnography

The Madera Ranch vicinity lies within the traditional homelands of the Northern Valley Yokuts (specifically the Huechi and Hoyima Yokuts), whose territory extended southward from just north of the Calaveras River to the bend of the San Joaquin River near Fresno. The foothills of the Diablo Range probably marked the western boundary of Northern Valley Yokuts territory, while the eastern boundary is at the lower foothills of the Sierra Nevada. The Northern Valley Yokuts made their livelihood through fishing and hunting and gathering various plant foods, especially acorns. Most principal settlements sat perched on top of low mounds, on or near the banks of large watercourses. The elevated positions helped to keep the inhabitants, their houses, and their possessions above the waters of the spring floods. A strong tendency toward residence in permanent villages, fostered by the abundant riverine resources, was evident; the same sites were occupied for generations (Kroeber 1925; Wallace 1978).

Historical Content

This historical context focuses on the development of irrigation in the Madera area because the three newly identified cultural resources (Main No. 2 Canal, 24.2 Canal, and Section 8 Canal) are associated with this theme. It should be noted that this section is derived from several sources. In some instances, these sources are not consistent with one another.

The development of large-scale irrigation literally changed the face of California by allowing the development of large-scale agriculture, residential and industrial power, and substantial new recreation areas. The Spanish and Mexicans had practiced irrigation on a limited scale by diverting water from streams to mission orchards, gardens, and pueblos via open ditches. The development of large farms in the post-gold rush era and a series of devastating droughts in the 1860s, however, provided the impetus for the construction of more extensive irrigation projects (Hart 1978:205).

In the late 1880s, the portion of present-day Madera County between the Chowchilla and San Joaquin Rivers and the lower Sierra foothills and Chowchilla Canal was one of the last large areas of the San Joaquin Valley with ready water sources at hand; yet it had relatively little land under irrigation. Following in the wake of the Wright Act, the Madera Irrigation District (not related to the present MID) was established in 1888, comprising 280,000 acres. Owners of large areas of land on the lower San Joaquin River, such as Miller & Lux, however, objected to the formation of the district and the proposed use of San Joaquin waters. Opposition to the newly formed district was bolstered by owners of large landholdings who were content with the methods of farming then in use in the region. The Madera Irrigation District found itself in a losing legal battle, with the prospect of extended litigation. The organizers of the district dissolved the entity in 1896 (Adams 1929:199; Barnes 1963:7; Harding 1960:100; Rodner 1948:6).

The Madera Canal and Irrigation Company (MC&IC) was a contemporary of the first Madera Irrigation District. The MC&IC used the Fresno River as its sole water supply and sold water rights to the MC&IC, formed in 1888, to —acquire, hold and dispose of water and water rights" (Barnes 1963:2). Flow from the Fresno River was supplemented by up to 100 cfs from the North Fork of the San Joaquin River, Big Creek, and Chilcoot Ditch. The MC&IC had rights to only 200 cfs from the Fresno River, which did not allow for adequate service to the canal company's customers. In addition, the organization suffered from a lack of available funding and insufficient maintenance and operation of the system (Adams 1929:200).

The conditions outlined above led to an interest in a larger irrigation project. An irrigation bureau was formed, and the manager of the MC&IC, R. L. Hargrove, filed a preliminary engineering report proposing to divert 3,000 cfs from the San Joaquin River and store some several hundred thousand-acre feet of water at the site of present Friant Dam. Subsequent investigations were conducted, and a plan was drawn up for a 350,000-acre irrigation district. The current MID was formed in 1920 and was immediately subjected to litigation from Miller & Lux, who opposed diversion of water from the San Joaquin River by MID. As a result of legal conflicts, the San Joaquin River Water Storage District was organized to include both Miller & Lux and MID land and to institute a suitable compromise to the interests of the former two groups. Agreement was never reached, however, and the storage district was dissolved in 1929 (Adams 1929; Madera Irrigation District 1981:3–6; Miller 1993).

Meanwhile, the state had conceived the State Water Plan and planned to construct Friant Dam and Reservoir. Anticipating state assistance with the development of a water supply for the district, MID purchased the Friant site. The water project was turned over to Reclamation, however, and MID waited until 1939 before being granted a water supply from Friant Dam, which was built in 1944 (Madera Irrigation District 1981:6). MID began supplying water to its customers in 1949, when the distribution system in the central part of the district was purchased from the MC&IC. The rest of MID distribution system was built in 1955 and 1959 by Reclamation. It is the last open-ditch irrigation system built by Reclamation in California (Madera Irrigation District 1981:6).

The building of the area's irrigation systems spurred development of the region's rich agricultural industry from the 1870s to the present. The growth of Madera County, in turn, is tied to the region's agricultural development. People began settling in Madera County to establish farming colonies. In time, several self-sufficient communities emerged, prompting the development of infrastructure and small industries. In present-day Madera County, logging, mainly of sugar pine, developed concurrently with other industries, such as copper and granite mining. Grapes, raisins, figs, cotton, alfalfa, fruit, cattle, and seed and field crops are historically important crops and remain significant today (Clough 1968; Madera County 2007).

Historical Research

Historical research identified two broad contexts within which to evaluate cultural resources identified in the Madera Ranch vicinity: ranching/agricultural pursuits and irrigation. Cultural resources related to ranching/agricultural pursuits are evaluated within a historic framework of the development of ranching in Madera County and the resources' association with the Pope and Talbot families. Research on irrigation identified historic canals built by Miller & Lux to irrigate range and agricultural lands; these resources are evaluated within the framework of Miller & Lux's role in the irrigation of the San Joaquin Valley. Later irrigation efforts that culminated in the formation of MID are an important subset of the irrigation theme.

Evaluation of cultural resources identified as a result of the present investigation indicates that the alternatives considered in this analysis would not affect historic, archaeological, architectural, or traditional cultural properties that appear to be eligible for inclusion NRHP because there are no such properties within the project area. However, the alternatives do have the potential to affect as-yet-unidentified cultural resources, such as buried archaeological sites. Effects could result from the physical disturbance of unidentified cultural resources during construction or construction-related activities.

The following discussion of cultural resources is based on a review of existing information regarding the prehistoric, ethnographic, and historical context of the Madera Ranch vicinity. Additional information was requested from the Native American Heritage Commission (NAHC) and from Native American individuals with knowledge of local resources of concern to Native Americans. Archaeologists conducted a preliminary field visit, consulted historic maps, and conducted a mixed-strategy survey of the vicinity to identify cultural resources. Additionally, historical research was carried out at statewide repositories in Sacramento and local repositories in the Madera vicinity to evaluate cultural resources identified in the field.

Prefield Research

A records search was conducted at the Southern San Joaquin Valley Information Center (SSJVIC) at California State University, Bakersfield, on April 7, 2000, and records search updates were requested on February 24 and March 7, 2005. Specific records reviewed at the SSJVIC included those from surveys previously conducted and sites previously recorded in and within a 0.5-mile radius of the Madera Ranch vicinity. The NRHP (including updates through January 2000 and March 7, 2005), the California Inventory of Historic Resources (California Department of Parks and Recreation 1976), California Historical Landmarks (California Department of Parks and Recreation 1996), and the California Register of Historical Resources (CRHR) also were reviewed.

The records searches indicate that one cultural resource study had been conducted in the project area of potential effect (APE) (Jones & Stokes 2002), and seven cultural resource investigations have been conducted within a 0.5-mile radius of Madera Ranch (Baloian and Flint 2002; Cannon 1986; Hudlow 2000; Nissley et al. 1975; Price 2001; Ptomey 1990; Riddell 1975). Consulting archaeologists (2002) recorded a total of 13 historic-era cultural resources in and adjacent to the present APE, on Madera Ranch. In addition to these resources, one prehistoric archaeological site (CA-Mad-300) and historic Cottonwood Creek Bridge (P-20-2323) have been recorded within a 0.49 mile radius of the APE (Feldman 2001; Hudlow 2000; Peak and Gerry 1975). CA-Mad-300 consists of three oval depressions and –several” round depressions thought to be prehistoric structural remnants. The site is located 1.24 miles south of Madera Ranch above a filled-in slough (Peak and Gerry 1975).

Historical Research

Historical research was conducted at the following repositories in Sacramento:

- library at California State University, Sacramento;
- California History Room of the California State Library;
- library of the California Department of Conservation, California Geological Survey;
- California State Archives; and
- Bureau of Land Management (BLM) cadastral survey records.

Research also was conducted at the following repositories in the Madera vicinity:

- the County library, Madera;
- the County Recorder’s and Assessor’s offices, Madera;
- MID, Madera;
- GFWD, Madera; and
- Columbia Canal Company, Firebaugh.

The results of this research are presented in the Historical Context section of the cultural resources inventory and evaluation report (Jones & Stokes 2002) and were used to evaluate the cultural resources identified in the field.

Native American Consultation

On April 4, 2000, March 3 and 7, 2005, and again on February 12, 2009, consultants requested that NAHC staff members in Sacramento conduct a search of the sacred lands file for cultural resources. NAHC personnel reported that no cultural resources listed in the sacred lands file are present in the Madera Ranch vicinity. They also provided the consultants with a list of interested Native American individuals and organizations that may have knowledge of cultural resources in the vicinity. The consultants contacted each Native American contact by letter and telephone. To date, this consultation has not yielded information regarding cultural resources in the vicinity.

Field Visit and Map Research

On May 30, 2000, two consulting archaeologists conducted a driving survey of the Madera Ranch vicinity to become familiar with current land use and access issues on the property and to identify areas sensitive for cultural resources. The information gathered during the field visit was used to design the cultural resources survey strategy and to identify potential effects on cultural resources.

During the field visit, the archaeologists mapped current land uses, topography, vegetation, and cultural resource locations on topographic maps of the area. The information obtained was cross-checked with aerial photographs of the vicinity. Historic maps were obtained from BLM survey records and the California Geological Survey Library, both in Sacramento. Potential cultural resource locations as indicated on historic maps were cross-checked with field notes and aerial photographs, resulting in the identification of eight cultural resources in the vicinity.

Field Survey The APE was systematically surveyed to identify cultural resources. In 2000, consulting archaeologists conducted an intensive pedestrian survey of 650 acres of the Madera Ranch property. The area was surveyed by walking transects spaced 100 feet between surveyors. In March 2005, the consulting archaeologists returned to the Madera Ranch vicinity to visit locations beyond the boundaries of Madera Ranch where construction would occur (i.e., along the Main No. 2, Section 8, and 24.2 Canals).

In March 2009, consulting archaeologists conducted further surveys of approximately 1,319 acres of the Madera Ranch property and 10 locations beyond the boundaries of Madera Ranch where construction would occur (i.e., adjacent to Cottonwood Creek and 24.2 Canal). These surveys included intensive pedestrian surveys and subsurface trenching of six areas identified as sensitive for buried cultural resources. The pedestrian survey was conducted by walking transects spaced 100 feet between surveyors. The subsurface trenching consisted of six 15-foot trenches with an average depth of 7 feet at six areas on Madera Ranch where paleosols were identified as a result of past geotechnical studies.

3.5.2 Environmental Consequences

As documented previously, cultural resources CA-Mad-2309-H, P-20-2385, P-20-2386, P-20-2389, P-20-2390, P-20-2393, P-20-2394, P-20-2398, P-20-2400, P-20-2402, , CA-Mad-2310-H, P-20-2399, the Main No. 1 Canal, the Main No. 2 Canal, the 24.2 Canal, and the Section 8 Canal, were evaluated previously under the NRHP's significance criteria. None of these resources were found to be eligible under the NRHP's significance criteria (Jones & Stokes 2002; ICF Jones & Stokes 2009) and SHPO concurred with these determinations on August 31, 2009 (Appendix E).

Alternative A—No Action

Under the No Action Alternative there would be no impacts to cultural resources. However, it is expected that under this alternative, conditions would change to support agricultural activities.

Alternative B—Water Banking Outside the MID Service Area and Alteration of Reclamation-Owned Facilities

Effect CR-1: Damage to or Destruction of Nine Historic Features on Madera Ranch through Construction of Recharge Basins Alternative B would result in damage to or destruction of nine historic features (CA-Mad-2309-H, P-20-2386, P-20-2389, P-20-2390, P-20-2393, P-20-2394, P-20-2398, and P-20-2400) on Madera Ranch as a result of the excavation of recharge basins. Brief resource descriptions are presented in Table 3-14. Consulting archaeologists (2002:26–29; 2007:46, 48–50, 52; ICF Jones & Stokes 2009:53-68) evaluated these nine resources for eligibility for listing in the NRHP and recommended all as ineligible for NRHP listing. Modification of these resources would not be considered an adverse effect on cultural resources.

Effect CR-2: Physical Modifications to Gravelly Ford Canal (P-20-2402) Alternative B would result in physical modifications to the GF Canal (P-20-2402) for use in the proposed water-collection system. Modifications would consist of grading the canal bottom and side slopes, as well as construction of three to five permanent canal crossings. Consulting archaeologists (2002:26; 2007:44) evaluated P-20-2402 for eligibility for inclusion in the NRHP and recommended the canal as ineligible. Modification of this resource would be considered no impact to cultural resources.

Effect CR-3: Physical Modifications to Historic Main No. 1, Main No. 2, and Section 8 Canal Alternative B would result in physical modifications to the Main No. 1, Main No. 2, and Section 8 Canals. Modifications include the installation of lift gates and other ancillary features and canal widening.

The Main No. 1, Main No. 2, and Section 8 Canals are components in the MC&IC system, which MID purchased for distributing water in 1949 (Madera Irrigation District 1981:6). The addition of the MC&IC canal system gave MID access to Fresno River and San Joaquin River water, increasing its service capabilities (Barnes 1963:3). The MC&IC portion of MID irrigation system is associated with the early development of irrigation in the Madera region, which promoted the cultivation of new and diverse crops. The period of significance for the Main No. 2 and the Section 8 Canals is therefore 1870–1920, the former date marking the approximate construction of the MC&IC system and the latter marking the inception of MID.

Because of the system's association with early irrigation and agricultural development, the Main No. 1, Main No. 2, and Section 8 Canals appear to meet NRHP Criterion A at the local level of significance. Main No. 1, Main No. 2 and Section 8 Canals do not, however, retain integrity of workmanship and design because MC&IC and MID have modified the canals through regular maintenance and redesign since 1920. These modifications resulted in water conveyance structures that do not resemble their historic antecedents but look like modern ditches and canals. As modern canals, the Main No. 1, Main No. 2, and Section 8 Canals do not physically convey their historical significance. Therefore, the Main No. 1, Main No. 2 and Section 8 Canals do not appear to be historic properties. Modification of these canals would not be considered an impact on cultural resources.

Effect CR-4: Physical Modification of 24.2 Canal Reclamation, under contract with MID, built 24.2 Canal in 1955 as a component of MID's distribution system (Madera Irrigation District 1981). Although certainly important in MID's service operations, construction of the system is not a historically important event. The 24.2 Canal is not associated with historically consequential persons and is not associated with the work of a renowned engineer. For these reasons, the 24.2 Canal does not appear to meet the significance criteria of the NRHP and would not qualify as a historic property. Modification of the 24.2 Canal would be considered no impact on a cultural resource.

Effect CR-5: Physical Disturbance of Currently Undiscovered Cultural Resources The present analysis is based on record searches and a review of prehistoric, ethnographic, and historic literature pertaining to the Madera Ranch vicinity; consultation with Native Americans; historical research; and a pedestrian survey of the vicinity (Jones & Stokes 2002, 2007, 2011). Despite the comprehensiveness of the cultural resources inventory, construction may unearth or reveal additional cultural resources that have not been recorded previously and may not have been visible during surveys conducted to date (Jones & Stokes 2007:39–42, 55). The physical disturbance of undiscovered cultural resources could result in an impact. Implementation of Environmental Commitment CR-1 to stop construction if cultural resources are discovered would reduce the intensity of the effect.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales will be used and a reduced number of ponds will be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. This would not result in any differences from what was described above for Alternative B relative to effects to cultural resources. The effects of Reduced Alternative B would result in nearly identical effects to those that would occur under Alternative B (Effects CR-1, CR-2, CR-3, CR-4 and CR-5), and thus, would be considered no impact to cultural resources.

Alternative C—Water Banking Outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. However, the expected footprint of recharge basins under Alternative C would be nearly identical to Phase 2 of Alternative B and would result in equivalent effects on cultural resources (Effects CR-1, CR-2, CR-3, CR-4, and CR-5). None of the cultural resources identified are eligible for inclusion in the NRHP. Thus, under NEPA, there is no impact to cultural resources. If cultural resources are discovered during construction (as described in Effect CR-5), it could result in an impact to cultural resources under NEPA. Implementation of Environmental Commitment CR-1 to stop construction if cultural resources are discovered would reduce the intensity of this effect.

Alternative D—Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B. However, the expected footprint of recharge basins under Alternative D would be nearly identical to Alternative B and would result in equivalent effects on cultural resources (Effects CR-1, CR-2, CR-3, CR-4, and CR-5). None of the cultural resources identified would be recommended for eligibility. Thus, there would be no impact to cultural resources unless cultural resources are discovered during construction (as described in Effect CR-5). Implementation of Environmental Commitment CR-1 to stop construction if cultural resources are discovered would reduce the intensity of this effect.

Cumulative Effects

Alternative B could result in the physical disturbance of undiscovered cultural resources. MID would halt construction if artifacts are discovered and require evaluation by a professionally qualified archaeologist. This would minimize effects on cultural resources and therefore would not result in a significant regional cumulative effects on cultural resources in Madera County.

As Reduced Alternative B and Alternatives C and D are equivalent to Alternative B in scope and effect, it is not anticipated these alternatives would contribute to cumulative impacts on cultural resources.

3.6 Environmental Justice

This section presents the environmental background necessary to analyze compliance with EO 12898 and provides background information on the ethnic and income characteristics of the study area.

On February 11, 1994, President Clinton issued EO 12898, Federal Actions to Address Environmental Justice in Minority and Low-Income Populations. The purpose of the order is to avoid the disproportionate placement of any adverse environmental, economic, social, or health effects from federal actions and policies on minority and low-income populations.

3.6.1 Affected Environment

To comply with Executive Order 12898, the most current U.S. Census Bureau demographic data available (http://quickfacts.census.gov/qfd/states/06/0645022.html) were analyzed at a geographic scale commensurate with the area of potential effect. The WSEP would be implemented west of the city of Madera in unincorporated Madera County. Consequently, the environmental justice assessment focused on an examination of the overall Madera County statistics and not the city of Madera (Table 3-15). Income and ethnicity variables for Madera County were analyzed to determine whether the county has a relatively high population of low-income or minority residents.

Table 3-15 Population and Percent Ethnicity Data for Madera County

Area	Total 2009 Population	White	African American	Native American	Asian	Hispanic
Madera County	148,632	87.6%	4.6%	3.3%	2.1%	51.7%
City of Madera	54,959	48.1%	3.9%	2.8%	1.4%	67.8%

Notes: All ethnicity data population data (city and county) are for 2009 U.S. Census State and County QuickFacts.

Population and Demographics

The total population of Madera County in 2000 was 148,632, a 20.7% increase between April 1, 2000 and July 1, 2009. Madera County is considered ethnically diverse; minority populations account for an estimated 38% of the county's total population.

Median household income for Madera County is $36,286. Persons in poverty were estimated at 21% of Madera County population for the 2000 census year (Table 3-16).

Table 3-16 Income Data for Madera County

Area	Median 2008 Household Income	Percent above Poverty Level	Percent below Poverty Level
Madera County	$46,000	79	21

Notes: Income data are from 2009 U.S. Census State and County QuickFacts.

3.6.2 Environmental Consequences

After the alternatives were selected, the environmental effects of the WSEP were reviewed and evaluated to determine whether they could result in disproportionate effects on minority or low-income populations. Implementation of the Proposed Action would be for a largely rural and undeveloped area of Madera County. According to a review of census data for 2009, both Madera County and the Madera Ranch area are considered similarly ethnically diverse. Minority populations account for an estimated 61.7% of Madera County's total population.

Although minority and/or low-income populations may be located in the vicinity of the Madera Ranch site, census data indicate that the overall percentage of minority and low-income populations located in the vicinity of Madera Ranch is fairly similar to that of the overall Madera County population. Consequently, the Madera Ranch area is not considered to be composed of a disproportionately high level of minority or low-income populations.

As described elsewhere in this chapter, environmental effects considered include traffic, land use, air quality, noise, public safety, and hazardous materials. None of the environmental effects identified for either the Proposed Action or any of the alternatives would affect a specific population group. Consequently, implementation of the Proposed Action would not disproportionately affect a specific ethnic or income group.

3.7 Geology, Soils, Seismicity, and Erosion

This section describes the geologic, seismic and soil conditions in the proposed action area. This section also includes the paleontological conditions in the Proposed Action area.

3.7.1 Affected Environment

In some instances, the affected area is extended to include land located outside the site (in the Madera Ranch vicinity) that could be affected by potential changes in the groundwater table resulting from the Proposed Action or alternatives.

Geology

The Madera Ranch site is located on the level and nearly level alluvial landforms that occupy the east-central flank of the San Joaquin Valley, a large northwest-trending structural trough filled with a thick layer of alluvial sediments (Bailey 1966). The regional geologic map compiled by Jennings and Strand (1958) indicates that the site is underlain by basin and alluvial fan deposits, which consist of gravels, sands, silts, and clays deposited by rivers and streams during the last 10,000 years. The basin and alluvial fan deposits are of similar age.

The basin deposits consist of instream, natural levee, and floodplain deposits that have been salinized in areas by groundwater. These salinized basin deposits serve as the primary parent material of the moderately and strongly saline-alkali soils that dominate the affected area. The alluvial fan deposits compose portions of the east-west–trending San Joaquin River, Fresno River, and Cottonwood Creek alluvial fans, which coalesce in the Madera area.

Land subsidence is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs; collapse of underground mines; drainage of organic soils; and initial wetting of dry soils.

Overdrafting of aquifers is the major cause of subsidence in the southwestern United States. In many aquifers, groundwater is pumped from pore spaces between grains of sand and gravel. If an aquifer has beds of clay or silt within or next to it, the lowered water pressure in the sand and gravel causes slow drainage of water from the clay and silt beds. The reduced water pressure is a loss of support for the clay and silt beds. Because these beds are compressible, they compact (become thinner), and the effects are seen as a lowering of the land surface. The lowering of land surface elevation from this process is permanent. For example, if lowered groundwater levels caused land subsidence, recharging the aquifer until groundwater returned to the original levels would not result in an appreciable recovery of the land-surface elevation.

In the San Joaquin Valley, most subsidence is correlated with reduced water pressure in confined aquifers. Subsidence from 1926 to 1973 occurred in significant amounts southwest of Madera County, with subsidence of 28 feet approximately 15 miles southwest of Madera Ranch and eight miles southwest of Mendota. During this period no subsidence was experienced at Madera Ranch (Bookman-Edmonston 2003). The County has indicated there has been some recent subsidence in the western portion of the county above the Corcoran Clay resulting from groundwater overdraft, but the amount was not described (Madera County 2008).

Soils

Soils in Madera County were surveyed by the NRCS during the 1950s (Stromberg et al. 1962). When the survey was conducted, much of the land in western Madera County was uncultivated and undisturbed so native soils were extensive in the vicinity of Madera Ranch. Since that time, many of the native soils in western Madera County have been physically and/or chemically altered from their natural condition by agricultural practices, such as subsoiling (ripping), saline-alkali soil reclamation, leveling, ditch construction, and groundwater pumping (which can lower the water table). Consequently, the descriptions of soils in these areas provided by the NRCS only describe the overall soil composition as there may be localized alterations.

Although all of the soils in these areas formed from alluvium derived primarily from granitic rock, the soil map units delineated by Stromberg et al. (1962) can be grouped into one of two general categories based on the relative age of the granitic rock alluvium from which they formed and the type of geomorphic surfaces on which they occur:

- soils formed from recent alluvial fan and floodplain deposits and
- soils formed from older alluvial fan and basin deposits.

The soils that make up each of these groups typically exhibit a common range of characteristics. For example, soils formed from older alluvial fan and basin deposits are more developed, exhibit substantial textural variation with depth, and typically are excessively saline and alkaline. In contrast, soils formed from recent floodplain and alluvial fan deposits typically are less developed, exhibit relatively little textural variation with depth, and are less affected by excess salinity and alkalinity. In general, the swales proposed for recharge as part of Alternative B Phase 1 are underlain by the relatively recent alluvial fan and floodplain deposits, which have lower salt content. The swales are mapped mostly as Pachappa series soils (described below).

Soils on older alluvial fan and basin deposits include those of the Fresno, El Peco, Traver, Dinuba, Chino, Borden, and Calhi series. They occupy the greatest proportion of total land area in Madera Ranch and support most of the alkali grasslands, slickspots, and alkali rain pools that exist on the uncultivated portions of the site. With the exception of the fine-textured and moderately fine-textured subsoil horizons (i.e., layers) that occur in some of these soils, they are typically coarse-textured and moderately coarse-textured throughout and are at least slightly saline-alkali.

Most of the older alluvial fan and basin soils on Madera Ranch also contain a lime-silica–cemented hardpan or a weakly cemented silty substratum at depths ranging from five to 36 inches below the ground surface. In their natural condition, these soils are slowly to moderately permeable, are moderately well- to somewhat poorly drained, and typically have relatively low organic matter content and low to moderate native fertility.

Soils of the Fresno and El Peco Series The moderately coarse-textured soils of the Fresno and El Peco series occupy the greatest proportion of land at Madera Ranch. The soils of both series occur on level and nearly level surfaces that, in their natural condition, frequently exhibit low, hummocky (mound-intermound) microrelief. They typically consist of sandy loams, fine sandy loams, silt loams, and loams to depths of more than 60 inches and contain a discontinuous, five-to six-inch-thick lime-silica–cemented hardpan at depths ranging from five to 36 inches below the ground surface.

Most of the Fresno and El Peco soils at the site are moderately to strongly saline-alkali. Because of the high content of exchangeable sodium and the water-restrictive duripans, these soils are very slowly permeable and somewhat poorly drained. Most of the slickspots and alkali rain pools that exist on the uncultivated portions of the site occur on moderately to strongly saline-alkali soils of the Fresno and El Peco series (not all mapped areas of these series support slickspots or alkali rain pools).

Soils of the Traver, Dinuba, Chino, and Borden Series The coarse-textured soils of the Traver series and the moderately coarse-textured soils of the Dinuba series are found in association with soils of the El Peco series on the southern half of the Madera Ranch site.

Soils of the Traver and Dinuba series are similar to the soils of the Fresno and El Peco series in that they typically consist of slightly to strongly saline-alkali sandy loams and fine sandy loams that exist on level and nearly level surfaces that frequently exhibit a low, hummocky microtopography. However, they typically do not contain a lime-silica–cemented hardpan, although soils of the Dinuba series are sometimes underlain by a weakly cemented layer of stratified silts and fine sands at depths ranging from 26 to 36 inches below the ground surface. Soils of the Dinuba and Traver series are slowly to moderately permeable. Because they lack a true duripan, they have better internal drainage than the soils of the Fresno and El Peco series.

Soils of the Chino series occur in nearly level, swale-like positions throughout Madera Ranch. They are similar to soils of the Traver series but consist of slightly finer textures and have poorer internal drainage.

Soils of the Borden series occur on nearly level surfaces near the northeast part of Madera Ranch. They differ from the soils of the Traver, Dinuba, and Chino series mainly in that they typically have a moderately clay-enriched subsoil horizon and are not as strongly affected by excess salinity and alkalinity. Soils of the Borden series have moderately slow permeability and are well-drained.

Soils of the Calhi Series Soils of the Calhi series occur in small areas throughout Madera Ranch. They formed from granitic alluvium that was reworked by wind, are slightly to moderately saline-alkali, and typically consist of loamy fine sands throughout. They generally occur on undulating ridges and small mounds within larger areas of Fresno, El Peco, and Dinuba soils. Because of their uniform, sandy texture and lack of subsurface restrictive layers, they have moderate permeability and good internal drainage.

Soils on recent alluvial fan and floodplain deposits include those of the Pachappa, Greenfield, Cajon, Wunjey, Tujunga, and Visalia series. They are less developed, less extensive, and show less morphologic variation with depth than the older basin and alluvial fan soils described above. These soils typically occur on level and nearly level surfaces and in long, swale-like positions that are often subject to continued alluvial deposition. They lack the fine-textured subsoil horizons and duripans found in the basin soils; with few exceptions, they are coarsely textured throughout and consist of loamy sands, sandy loams, and fine sandy loams to depths of more than 60 inches.

Most of the recent alluvial fan and floodplain soils are not as severely affected by excess salinity and alkalinity as the soils formed from older alluvial fan and basin soils. They typically have moderate to rapid permeability, are moderately well to somewhat excessively drained, and are characterized by low organic matter content and low native fertility.

Soils of the Pachappa and Greenfield Series The coarse- and moderately coarse-textured soils of the Pachappa and Greenfield series formed from the oldest of the recent alluvial fan and floodplain deposits that exist at Madera Ranch. Soils of the Pachappa series occupy relatively large areas throughout the site, while soils of the Greenfield series are much less extensive. The soils of both series typically are located on nearly level surfaces in narrow, swale-like positions that are not usually subject to continued alluvial deposition; they generally consist of fine sandy loams and sandy loams with the slightly finer-textured subsoil horizons.

Soils of the Pachappa and Greenfield series are, at most, slightly affected by excess salinity and alkalinity near the surface, but they become moderately to strongly saline-alkali with depth. The soils of both series typically are moderately rapidly permeable and well-drained, but they support many of the vernal pools that occur at the site.

Soils of the Cajon, Grangeville, Wunjey, Tujunga, and Visalia Series The coarse-textured soils of the Cajon, Grangeville, Wunjey, Tujunga, and Visalia series formed from the youngest of the recent alluvial fan and floodplain deposits at Madera Ranch. The soils of these series typically are located on nearly level surfaces and in narrow, swale-like depressions that can be subject to continued alluvial deposition; they generally show little textural variation with depth and consist of sandy loams, loamy sands, and sands that are moderately rapidly permeable and moderately well- to somewhat excessively drained. The soils of the Cajon, Grangeville, Wunjey, and Visalia series are slightly to strongly saline-alkali; soils of the Tujunga series typically are nonsaline and nonalkali throughout.

Subsurface Soils Extensive data have been collected on the subsurface geology of the property (Bookman-Edmonston 2003). These findings include:

- an average of 260 feet of sediments are deposited above the Corcoran clay beneath Madera Ranch;
- since the Pleistocene, the migration of rivers has produced a network of thick overlapping bands of sandy channel deposits trending from east-northeast to west-southwest;
- five major stratigraphic units were identified above the Corcoran clay;
- the Corcoran clay is discontinuous under the eastern and southeastern portion of the property and is continuous under the western portion of the property;
- approximately 13% of the aquifer material is clayey, 28% is silty, and 59% is sandy;
- the most extensive clayey zones occur at depths of about 70 to 100 feet; and
- there are no identified fault zones under the project site.

Saline-Alkali (Salt-Affected) Soils As discussed above, most of the soils at Madera Ranch, especially those formed from older alluvial fan and basin deposits, are classified as saline-alkali. The properties of and classification system for these soils are discussed in detail below.

Properties and Classification The term saline-alkali is somewhat ill-defined, but, in general, it is applied to soils that contain sufficient salinity, alkalinity, and/or exchangeable sodium to interfere with the growth of most agricultural crops. Stromberg et al. (1962) assigned the saline-alkali soils in Madera County to three categories based on soluble salt content (salinity) and the effect of alkalinity on plant growth (Table 3-17).

Table 3-17 Categories of Saline-Alkali Soils in Madera County

Category	Soluble Salt Content[a]	Effect of Alkalinity on Plant Growth[b]
Normal	< 0.2	No significant
Slightly saline-alkali	0.2–0.5	Slight
Moderately saline-alkali	0.5–1.0	Moderate
Strongly saline-alkali	> 1.0	Strong

Source: Stromberg et al. 1962.

Notes: [a] A measure of soil salinity; percentage on dry-weight basis.

[b] A qualitative measure of soil alkalinity.

According to this system, soils classified as strongly saline-alkali are more likely to have a substantial effect on plant growth than soils classified as moderately or slightly saline-alkali. Although Stromberg et al. (1962) did not state explicitly what part of the soil profile the above categories refer to, soil profile descriptions provided in the Madera area soil survey suggest that they refer to conditions in the topsoil layers, which are the layers in which most plant roots are found. This interpretation is consistent with the fact that many soils classified as slightly saline-alkali by Stromberg et al. (1962) have slightly alkaline topsoils but moderately to strongly alkaline subsoils.

The classification system presented in Table 3-17 is no longer used by the NRCS for the purpose of classifying salt-affected soils. It has been replaced by a new system that was developed by workers at the U.S. Salinity Laboratory (Table 3-18). Most of the saline-alkali soils at Madera Ranch probably would be classified as saline-sodic or sodic under the new system, although it is difficult to determine for certain because of the paucity of available chemical data for soils in Madera County.

Table 3-18 Current Classification Scheme for Salt-Affected Soils

Category	Electrical Conductivity of Saturated Soil Extract[a] (deciSiemens per meter)	Soil pH[b]	Exchangeable Sodium[c]
Normal	< 4.0	< 8.5	< 15
Saline	> 4.0	< 8.5	< 15
Sodic	< 4.0	> 8.5	> 15
Saline-sodic	> 4.0	< 8.5	> 15

Notes: [a] A measure of soil salinity.

[b] A function of soil alkalinity.

[c] Percentage on a dry-weight basis.

The terms *soil salinity*, *soil alkalinity*, and *exchangeable sodium* are defined below, as are the detrimental effects that each of these soil parameters can have on soil properties and plant growth when present in excessive quantities.

- *Soil salinity*: The amount of soluble salts (e.g., sodium chloride) present in a soil. The main effects of high soil salinity are stunted plant growth and poor seed germination. The mechanisms responsible for these effects are primarily osmotic: soluble salts have a strong affinity for water, so when they are present in high concentrations, they make it difficult for plants to extract water from the soil. Specific salt ions, such as sodium (Na^+), can have toxic effects on some plant species and can induce nutrient imbalances if present in sufficient quantities.
- *Soil alkalinity*: The degree or intensity of alkalinity in a soil. Alkalinity can be measured directly by summing the concentrations of bicarbonate and carbonate in a soil solution, or it can be calculated from soil pH. Soils with appreciable alkalinity typically have pH values greater than 7.0. The main effect of high soil alkalinity is to increase soil pH and reduce the availability of essential plant nutrients. Alkalinity induces precipitation reactions that remove nutrients, such as iron and calcium, from the soil solution, making them unavailable to plants.
- *Exchangeable sodium*: The fraction of a soil's cation exchange capacity that is occupied by sodium ions. Exchangeable sodium is a direct function of a soil's soluble salt content and usually is determined by measuring the ionic concentration of sodium in a saturated soil extract. The main effect of high levels of exchangeable sodium is on the physical properties of the soil, which in turn affect plant growth. When soil salinity is low, exchangeable sodium disperses soil clays and destroys the soil structure, interfering with the ability of plant roots to obtain necessary air and water. Because exchangeable sodium reduces soil permeability and infiltration rates, it can increase runoff and erosion. High levels of exchangeable sodium also can induce nutrient deficiencies by displacing other essential plant nutrients from the soil's exchange complex. When soil salinity is high, the detrimental effects of exchangeable sodium are generally less evident because high concentrations of soluble salts help keep soil clays flocculated (i.e., clustered in aggregates or flocks).

Sources of Soluble Salts in Madera Ranch Soils The chemical composition of soluble salts commonly found in soils can be traced to many sources. Some of the most common and significant sources include mineral weathering reactions, groundwater, and human-caused inputs such as fertilizer and irrigation water.

The excess quantities of soluble salts found in Madera Ranch soils are derived primarily from mineral weathering reactions, shallow groundwater, and surface floodwaters temporarily retained in the soil pore space by restrictive subsoil horizons, such as the lime-silica–cemented hardpans that occur in soils of the Fresno and El Peco series (Stromberg et al. 1962). Largely because of the San Joaquin Valley's semiarid climate, soluble salts from these sources have accumulated gradually over time, resulting in the saline soil conditions that exist in much of western Madera County. The fact that many of the saline soils at Madera Ranch are alkaline and contain excess exchangeable sodium (i.e., are saline-alkali) suggests that sodium bicarbonate constitutes a significant proportion of the accumulated salts.

Saline-Alkali Soil Reclamation To improve the suitability of saline-alkali soils for agricultural crop production, the soils typically must be treated with chemical amendments, such as gypsum and elemental sulfur, and large volumes of high-quality irrigation water. This practice is commonly referred to as soil reclamation. Gypsum is applied to displace exchangeable sodium from the soil, and the elemental sulfur is used to neutralize excess soil alkalinity. Gypsum- and sulfur-amended soils are subsequently flood irrigated to flush excess salts and displaced sodium ions from the root zone. The reclamation process typically is repeated until soil drainage and aeration improve and soil salinity and pH reach acceptable levels.

The proposed pond areas that would be affected by the alternatives were dry land farmed agriculture intermittently in the 1930s through 1970s. Crops that have been grown in these sections include row and forage crops, such as sugar beets, alfalfa, barley, and wheat, all of which have good to moderate salt tolerance. Agricultural lands were reclaimed (i.e., treated with gypsum and/or sulfur) in the past (Roughton pers. comm. [1]). The rest of Madera Ranch is grazed and probably has not been subject to reclamation efforts.

Slickspots and Alkali Rain Pools Slickspots, also referred to as panspots, alkali scalds, and small playas, are commonly occurring features in the uncultivated and marginally disturbed portions of Madera Ranch. They are located primarily on nearly level surfaces underlain by the moderately to strongly saline-alkali soils of the Fresno, El Peco, Traver, and Dinuba series. Although they vary considerably in size and form, the slickspots on Madera Ranch typically consist of relatively shallow, oval, and irregularly shaped depressions that range in size from a few square feet to more than 0.5 acre.

The slickspots that pond water for significant duration during the wet season are classified as alkali rain pools, a specific type of seasonal wetland (see Biological Resources Section). The slickspots on Madera Ranch are largely devoid of vegetation but are rimmed with salt- and alkali-tolerant plant species.

The soil survey of the Madera area indicates that the pre-1962 distribution of slickspots in the county was fairly extensive (Stromberg et al. 1962). Like the slickspots on Madera Ranch, they were located primarily in uncultivated areas underlain by moderately and strongly saline-alkali soils of the Fresno, El Peco, Dinuba, and Traver series, primarily in the westernmost portions of Madera County. Many of these areas since have been cultivated for agriculture, resulting in a significant reduction in the number and distribution of slickspots in the county.

Although no exhaustive statewide surveys have been conducted, the consensus is that slickspots in California form primarily on sodic soil landscapes in the Sacramento and San Joaquin Valleys and in smaller, nearby valleys, such as the Carrizo Plain (Reid et al. 1993, Arroues pers. comm.). Because many, if not most, of these landscapes also have been cultivated for agriculture, it is reasonable to assume that the statewide distribution of slickspots also has been reduced significantly. A review of historical aerial photographs contained in soil surveys of counties in the San Joaquin and Sacramento Valleys generally supports this conclusion; it indicates that a significant proportion of the remaining uncultivated sodic soil landscapes that contain slickspots are located in wildlife refuges and natural areas that have been protected for their species diversity and habitat value.

Seismicity

Well-defined, active earthquake faults are almost nonexistent on the alluvial plains of the San Joaquin Valley. Most known faults that exist in the San Joaquin Valley show no evidence of displacement during the last 1.6 million years (i.e., precede the Quaternary period and therefore are considered inactive) and are concealed by overlying sediments. Known faults in the immediate vicinity of Madera Ranch are of this type and include two unnamed fault traces located approximately two miles southwest of Madera Ranch (Jennings 1994). These fault traces do not present a hazard of ground surface rupture for the WSEP. No known active faults cross the Madera Ranch site (Hart and Bryant 1997). All known active faults in the San Joaquin Valley and surrounding mountain ranges are located more than 20 miles from the site.

Seismic ground-shaking has been identified as the primary seismic hazard in Madera County (Madera County 1995a). In the western portion of the county, unconsolidated alluvial sediments, which amplify the destructive energy of seismic waves to a greater degree than hard bedrock, are the main geologic substrate and potential risk. Only low levels of ground shaking would be expected to occur in the eastern and central portions of the San Joaquin Valley during the maximum probable earthquake on the San Andreas fault (located approximately 60 miles west of the proposed site) (Madera County 1995a). While seismic ground-shaking is identified as the primary seismic hazard in Madera County, the hazard is relatively low compared to other regions of California that are located closer to active fault systems.

The findings of the California Division of Mines and Geology probabilistic seismic hazard assessment are generally consistent with those of the *Five County Seismic Safety Element* prepared by the Tulare County Council of Governments for the counties of Fresno, Kings, Tulare, Madera, and Mariposa in 1974 (Tulare County Council of Governments 1974). The five-county hazard assessment indicated that only relatively low levels of ground-shaking would be expected to occur in the eastern and central portions of the San Joaquin Valley during the maximum probable earthquake on the San Andreas fault (magnitude 8–8.5 on the Richter scale) (Madera County 1995a). Thus, although seismic ground-shaking is the most significant type of seismic hazard in the Madera area, both of the above seismic hazard assessments indicate that the hazard is relatively low compared to other regions of California that are located closer to active fault systems.

Water and Wind Erosion Hazards Water and wind erosion are processes by which individual soil particles are detached and transported from one location to another by rain and the shear forces of wind and overland water flows. The most direct and detrimental effects of water and wind erosion are the loss of nonrenewable topsoil resources, the degradation of soil quality, and the degradation of air and receiving-water quality.

The poorly structured, fine sandy loam surface soils that occupy most of Madera Ranch have high erodibility. However, the prevailing slope gradient on the site is extremely low (typically 0–1%). Therefore, the rate of runoff is slow and the hazard of water erosion, even under disturbed conditions, is slight to nonexistent (Stromberg et al. 1962).

As with water erosion, the susceptibility of a given soil to wind erosion depends largely on inherent soil properties, such as organic matter content, coarse-fragment (e.g., gravel) content, aggregate stability, calcium carbonate content, and, most importantly, soil texture.

The NRCS established wind erodibility groups. All the soils on proposed action site belong moderately susceptible to highly susceptible wind erodibility groups.

Paleontological Resources

A number of geologic units in the project area have some potential to contain paleontological resources. These include the Modesto Formation, Riverbank Formation and Turlock Lake Formation. The Turlock Lake Formation is overlain by the Riverbank Formation which is overlain by the Modesto Formation. The following discussion provides additional information on these formations, which are considered particularly sensitive on a regional basis. Other units are also locally sensitive.

Quaternary alluvial and fluvial strata flooring the Central Valley record erosional dissection of the Sierran and Coast Ranges uplifts. Fossil remains of vertebrates are common in Pleistocene units throughout California, and Pleistocene alluvial units in particular can contain diverse vertebrate fauna representing various evolutionarily important taxa. Sloths, horses, camels, mammoths, and bison have been collected from middle to late Pleistocene sediments in many areas throughout central California (Jefferson 1991, Dundas et al. 1996, Hilton et al. 2000). Vertebrate mammalian fossils have proved helpful in determining the relative age of alluvial fan sedimentary deposits (Louderback 1951, Savage 1951, Albright 2000). Mammalian inhabitants of the Pleistocene alluvial fan and floodplain included mammoths, horses, mastodons, camels, ground sloths, and pronghorns. The Pleistocene epoch, known as the –great ice age,” began approximately 1,800,000 years ago.

Diverse vertebrate fauna, dominated by large herbivorous mammals, were discovered in May 1993 at the Madera County Landfill in alluvial fan, fan channel, and marsh/lacustrine (sedimentary lake deposits) sediments representing the upper unit of the Turlock Lake Formation. A late Irvingtonian age is indicated for the fauna. The fossil-bearing stratum normally is magnetized and is inferred to have an upper bound on the age of the fauna at 780,000 BC. The site location in Fairmead, California, where these fauna were discovered is approximately 16 miles from the project site. Because the geologic units that exist at the fossil discovery site in Fairmead are also present at the subject project site, the potential for similar paleontological resources to be present is high (Dundas et al. 1996).

The Modesto Formation, which is Late Holocene/Early Pleistocene in age, is present in the immediate vicinity of the project area. The formation is composed of alluvium derived from the interior of the Sierra Nevada upper fans and terraces as well as fine-grained stratified alluvium of flood basins and lower fans. Also present is the Turlock Lake formation, which is late Pleistocene in age and is composed of undifferentiated alluvium. Turlock Lake is the older of these formations and the Modesto Formation is the younger.

The Modesto Formation can be divided into an upper and lower member (i.e., distinct upper and lower levels), both of which occur in the project area. The lower member of the Modesto is composed of consolidated, slightly weathered, well-sorted silt and fine sand, locally containing gravels. Age estimates for the lower member range from 42,000 to 73,000 years BP. The upper member of the Modesto Formation is composed of unconsolidated, unweathered gravel, sand, silt, and clay. These deposits form alluvial terraces that are topographically higher than those of the lower member. Age estimates for the upper member range from 12,000 to 26,000 years BP (Dundas 1996).

A unit that is not present locally and surficially at Madera Ranch, but is known to have been deposited between the Modesto and Turlock Lake Formations, is the Riverbank Formation, which consists of approximately 10 to 13 feet of massive clayey sand. All three formations serve as ideal preservation environments for paleontological resources. The Modesto Formation and Upper Riverbank Formation are considered to be Rancholabrean, and the Lower Riverbank Formation and Turlock Lake Formation are considered to be Irvingtonian.

Surveys of Late Cenozoic land mammal fossils in northern California have been provided by Hay (1927), Stirton (1939), Savage (1951), Lundelius et al. (1983), and Jefferson (1991a, 1991b). On the basis of his survey of vertebrate fauna from the nonmarine Late Cenozoic deposits of the San Francisco Bay region, Savage (1951) concluded that two major divisions of Pleistocene-age fossils could be recognized: the Irvingtonian (older Pleistocene fauna) and the Rancholabrean (younger Pleistocene and Holocene fauna). These two divisions of Quaternary Cenozoic vertebrate fossils are widely recognized today in the field of paleontology. The age of the more recent Pleistocene, Rancholabrean fauna was based on the presence of bison and on the presence of many mammalian species that are inhabitants of the same area today. In addition to bison, large land mammals identified as part of the Rancholabrean fauna include mammoths, mastodons, camels, horses, and ground sloths (Dundas 1996).

Remains of land mammals have been found at a number of localities in alluvial deposits of the Modesto Formation or the Riverbank Formation. These units are Pleistocene in age, and remains discovered in these units would be considered fossils. Thus action-related activities may have an effect on paleontological resources if conducted on these units and resources are present. No paleontological resources have been discovered in the course of dozens of soil test-pits conducted for the project, but there remains a potential for them to be present.

3.7.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative, there would be no adverse effects on geologic resources. However, the future conditions would change to support agricultural activities. Potential effects would be evaluated by the County under CEQA, depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect GEO-1: Potential Exposure of People or Structures to Substantial Adverse Effects Resulting from Liquefaction Based on existing conditions, the potential for liquefaction to occur in Madera County is low. Implementation of Alternative B would raise the groundwater table to depths as shallow as 30 feet below the ground surface in places under and near Madera Ranch; however, it would not increase the potential for liquefaction because soils and sediments on and in the vicinity of Madera Ranch generally are not susceptible to liquefaction. Additionally, there would be few structures constructed as part of this alternative, and it is not expected that the risk to people or structures would change. As such, there would be no effect.

Effect GEO-2: Potential Subsidence Caused by Groundwater Overdraft The potential for subsidence on Madera Ranch is low to moderate depending on subsurface geological effects influenced by the location of application of banked water and the location and depth of recovery of banked water. Banking of water would be located in areas with the greatest percolation capacity, including the swales that have historically supported natural percolation. Recovery of banked water would be from a depth above the confined aquifer and would not directly affect the confined aquifer. However, operations would indirectly affect recharge to the confined aquifer and directly affect the seepage stress across the Corcoran clay underlying Madera Ranch. In the east of the site, the Corcoran clay is thin and the area tends to respond as a single unconfined aquifer, making subsidence in this area unlikely. On the western portion of the site, the Corcoran clay is thicker and project operations could have an effect on head differences above and below the Corcoran clay (Bookman-Edmonston 2003). No substantial increases in subsidence are expected to occur because pumping would be above the Corcoran clay, MID would leave 10% of the banked water in the aquifer, and the MROC would monitor the effects on ground surface elevations and would restrict project operations if subsidence is observed. As such, there would be no adverse effect.

Effect GEO-3: Potential Risks to Property Caused by Construction on an Expansive Soil Most of the soils and sediments on which facilities would be constructed are coarse- and moderately coarse-textured and would not be classified as expansive according to Table 18-1-B of the Uniform Building Code. However, some portions of the area in which facilities would be constructed are in areas with expansive soils. All of the facilities would be engineered and designed according to the Uniform Building Code in order to prevent any structural damage from soil expansion and contraction. There would be no effect.

Effect GEO-4: Potential Loss of a Substantial Amount of Topsoil from Land Grading Operations Topsoil materials would be stripped from all areas to be graded, temporarily stockpiled, and reapplied as a top-dressing once final grade is attained. There would be no effect.

Effect GEO-5: Increase in Wind and Water Erosion Rates during and Shortly after Construction The extensive land- and soil-stockpiling activities could cause a temporary increase in wind and water erosion rates. Such increased rates would occur during and shortly after construction. The potential for land-grading and soil-stockpiling activities to have such an effect on erosion rates would be greatest in a groundwater recharge basin, where the volume of soil disturbed and changes to existing slope gradients would be the most extensive.

An increase in wind erosion rates could result in the loss or redistribution of soil material and could have an adverse effect on air quality. However, the consequences of increased water erosion rates during and shortly after construction would vary considerably with the location.

To control water and wind erosion during construction, MID will prepare a Storm Water Pollution Prevention Plan (SWPPP) in compliance with the requirements of the National Pollutant Discharge Elimination System (NPDES) General Construction Permit, and the Central Valley Regional Water Quality Control Board (RWQCB) would administer the SWPPP (Environmental Commitment WQ-1a). The SWPPP would prescribe temporary Best Management Practices (BMPs) to control accelerated wind and water erosion during and shortly after construction and permanent BMPs to control erosion and sedimentation once construction is complete. The County would require that MID prepare an erosion-control plan and obtain a grading permit before initiating construction of facilities. This effect is not considered adverse.

Effect GEO-6: Increase in Long-Term Wind and Water Erosion Rates Extensive land-grading activities that would be undertaken during construction temporarily would increase the hazard of erosion at the Madera Ranch site by increasing slope gradients and exposing highly erodible soils to erosion by wind and water. The potential for an action alternative to have such an effect would be greatest in the groundwater recharge window, where the volume of soil disturbed and changes to existing slope gradients would be the most significant.

Once construction is complete, all graded surfaces, including the soil disposal areas located between the groundwater recharge basins, would be revegetated by re-applying stockpiled topsoil using methods to be described in the SWPPP.

The SWPPP may specify that topsoil will be stripped from the footprint of the recharge basins during initial grading operations, temporarily stockpiled, and reapplied to the surfaces of the soil disposal piles once final grade is established. The strippings, which would contain the rhizomes and seeds of native and naturalized grasses and forbs, would serve as the main seedbank for revegetation. Topsoiling is intended to establish native and naturalized vegetation to control potential wind and water erosion. The vegetation should be sufficient to stabilize the soil disposal piles and maintain erosion rates at or near preconstruction levels once construction is complete. However, many of the topsoils that exist in the footprint of the Phase 2 groundwater recharge basins are at least slightly saline-alkali.

Although many of the soils in these areas have been partially reclaimed for agricultural purposes (Roughton pers. comm.[1]), most probably still contain excess salinity, alkalinity, and exchangeable sodium, which can limit soil infiltration capacity and permeability and interfere with normal plant growth and seed germination. Repeated handling of weakly structured topsoil materials during grading operations would degrade the soil structure, which would exacerbate the adverse effect of excess exchangeable sodium on soil infiltration capacity. Therefore, the chemical and physical properties of the topsoil materials that would be applied to the surfaces of the soil disposal piles for revegetation purposes could cause significant runoff and interfere with the establishment and survival of vegetation. As a result, wind and water erosion rates could increase above preconstruction levels.

The degree to which soil salinity, alkalinity, and exchangeable Na+ would retard vegetation establishment in topsoiled areas is unknown because of the variability in depth of excavation, distribution of salts throughout the soil profile, and other factors. As an example, the vegetation at a pilot infiltration pond that was constructed in 2000 fully established in a reasonable amount of time, although the area was mapped as strongly saline-alkali, the applied soil was not segregated, and disturbed areas were not seeded.

However, if vegetation does not sufficiently establish (i.e., minimum of 70% vegetative cover one year after application) in topsoiled areas, substantial accelerated erosion could occur. This effect could be adverse, unless measures were implemented to promote vegetation growth.

Implementing of Environmental Commitment GEO-1, Amend Soils as Required in Topsoiled Areas, in the event of insufficient vegetation establishment would reduce the intensity of this effect.

Effect GEO-7: Potential Destruction of a Unique Pedologic Feature Research indicates that soil slickspots are a unique pedologic feature that occurs on sodic soil landscapes throughout the United States. In California, they once occurred primarily on alluvial landforms in the San Joaquin and Sacramento Valleys. However, because of the extensive agricultural development that has occurred in these areas, the abundance and distribution of slickspots in California have been reduced significantly. Consequently, slickspots have become somewhat rare.

Some of the groundwater recharge basins and other elements of Alternative B are proposed in areas supporting generally undisturbed soil slickspot terrain. Permanent effects on such terrain could extend over more than 300 acres. Grading and excavation to form the recharge basins and other elements could permanently destroy the slickspots. This effect is considered adverse because it could result in the loss of unique, nonrenewable pedologic features.

Implementing Environmental Commitment BIO-1, Establish a Grasslands Conservation Easement, would reduce the extent and intensity of this effect because the easement at Madera Ranch would incorporate an area larger than the area subject to long-term degradation: (2 acres conserved: 1 acre affected for swales) or permanent loss (3 acre conserved: 1 acre lost).

Effect GEO-8: Potential Soil Salinization from Elevated Groundwater Levels Alternative B could raise existing groundwater elevations (and salinity) significantly. In certain areas on and near the Madera Ranch site, an elevated water table could result in the salinization of the root zones of economically important, deep-rooted fruit and nut crops that occur in the vicinity of the site and could thereby adversely affect their growth.

Simply defined, *salinization by groundwater* is a process by which excess soluble salts are concentrated in the soil (root zone) during the evapotranspiration (ET) of saline groundwater. The mechanisms involved in this process vary, depending on the location of the water table relative to the root zone.

When groundwater is shallow enough to occupy all or a portion of the root zone, ET occurs directly from the water table. Salts dissolved in the groundwater are left behind in the process and accumulate in the root zone, where they can have various adverse effects on soil properties and plant growth.

When the water table is beneath the lower boundary of the root zone, the process of salinization by groundwater is somewhat more complex. In such a situation, plant roots cannot access the groundwater directly, and evaporation of groundwater at the soil surface can be negligible. However, groundwater and dissolved salts can move upward into the root zone in response to the water potential gradient (i.e., the potential for water to move upward) that exists between the surface of the water table and overlying soil materials. Once in the root zone, the groundwater can evaporate at the soil surface and be transpired by vegetation. In this case, soluble salts in the groundwater are left behind and accumulate in the root zone, as described above. Because the capillary forces that arise as a result of the interaction between water and soil are a major driving force in this upward movement of groundwater, the process frequently is referred to as *capillary flow* or *capillary rise*, and soil salinization resulting from capillary flow frequently is referred to as *capillary salinization*.

The upward, capillary flow of groundwater can be extensive (several yards), but the rate of flow generally decreases with increasing height above the water table. Because the rate of salt movement is in proportion to the rate of water movement, it also decreases with increasing height above the water table. The distance at which the rate of capillary flow becomes too small for any significant upward movement of salt is defined as the *critical capillary height* (H_c) (Smedema and Rycroft 1983). The critical capillary height is primarily a function of soil texture, with fine-textured soils generally having greater values than coarse-textured soils. Because the upward movement of salt is the product of the capillary flow rate and the salt content, H_c also increases with the salt content of the groundwater. Characteristic values of H_c for some common soil textures are as follows:

- sand, 19.6-29.5 inches;
- loamy sand and sandy loam, 39.3-59.0 inches;
- loam, clay loam, and clay, 39.3-59.0 inches; and
- fine sandy loam and silt loam, 39.3- 78.7.

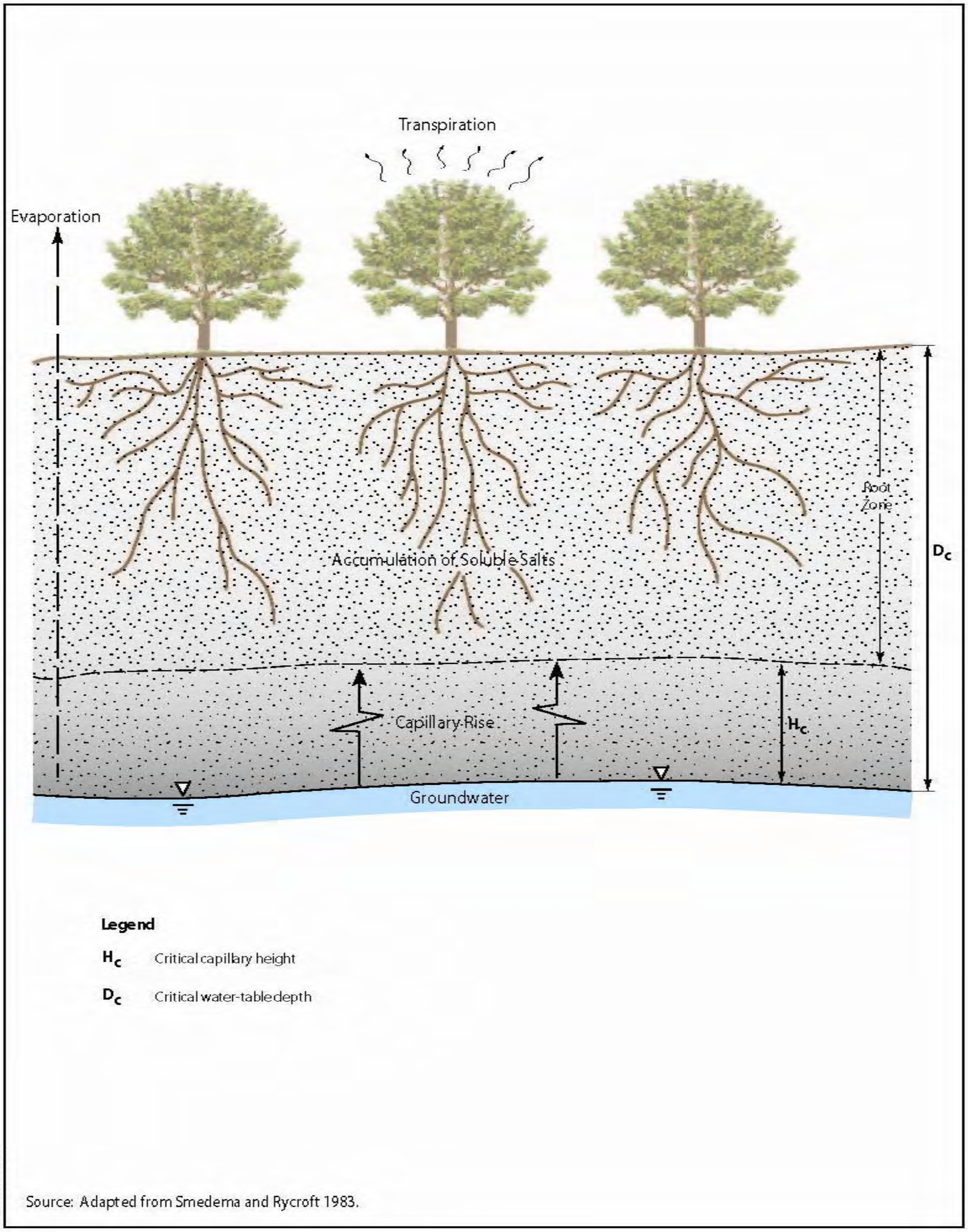
If the water table falls below a certain elevation, known as the *critical water-table depth* (D_c) (Figure 3-6), the capillary zone (H_c) will not extend into the root zone, and capillary salinization will not occur. If the water table is located above the critical water-table depth, capillary salinization is possible (Figure 3-6). Regardless of the depth of the water table or the value of Hc, there will be little capillary salinization of the root zone if the salinity of the groundwater remains less than 1,000 milligrams per liter (mg/l) (i.e., Electrical Conductivity less than 1.5 deciSiemens/meter) (Smedema and Rycroft 1983).

A soil scientist determined the potential for water tables affected by Alternative B to salinize the soil (root zone) in Madera Ranch. To do so, the soil scientist calculated D_c based on a worst-case estimate for the value of H_c and a reasonable estimate of the maximum rooting depth for three common, deep-rooting fruit and nut crops grown at Madera Ranch: almonds, grapes, and pistachios.

Almond-tree roots have been found as deep as 25 feet in Madera County (Holtz pers. comm.); however, University of California Extension farm advisors indicate that a reasonable estimate of the maximum rooting depth of almonds, grapes, and pistachios in a relatively uniform soil with no restrictive layers (i.e., slowly permeable soil horizons) is approximately eight–10 feet (Ferguson pers. comm., Freeman pers. comm.). Assuming that the value of H_c at Madera Ranch is at most 6.5 feet, the value of D_c would be approximately 14–17 feet below the ground surface. Because Alternative B would be operated and constrained so that affected water tables would not reach elevations higher than 30 feet below the ground surface at the Madera Ranch site boundary (i.e., would not extend above D_c), groundwater would not cause salinization of the root zones of important, deep-rooting agricultural crops surrounding Madera Ranch. Therefore, there would be no effect.

Effect GEO-9: Potential Destruction of a Sensitive Paleontological Resource Sensitive paleontological resources (e.g., fossils, trackways) have been reported in various sediments in the San Joaquin Valley, particularly in the relatively older (and usually deeper) geologic formations. Because the near-surface sediments underlying the site are geologically young and because the depth of excavation would be fairly shallow, there is a relatively low probability that excavation activities would disturb buried fossils. Nevertheless, because the possibility exists for a sensitive fossil to be discovered, the potential exists for Alternative B to destroy a sensitive paleontological resource, resulting in an adverse effect.

Implementing Environmental Commitment GEO-2, Stop Work in Event of Fossil Discovery, would minimize the intensity of the effect.



Source: Adapted from Smedema and Rycroft 1983.

Figure 3-6 Capillary Salinization of the Root Zone by Groundwater

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales will be used (550 acres versus 700 acres as proposed under Alternative B) and a reduced number of basins will be constructed (323 acres versus up to 1,000 acres under Alternative B). Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. Because Reduced Alternative B would use fewer swales and limit the number of recharge basins, the potential for erosion by wind and water due to extensive land-grading activities and potential for destruction of a sensitive paleontological resource or unique Pedologic Feature (Effects GEO-6, GEO-7, and GEO-9) would be reduced. Under Reduced Alternative B, effects on geologic resources (Effects GEO-1, GEO-2, GEO-3, GEO-4, GEO-5, GEO-6, GEO-7, GEO-8, and GEO-9) would be considered minor, except for the loss of soil slickspot terrain (Effect GEO-7) and the potential loss of paleontological resources discovered during construction (Effect GEO-9), which are considered adverse. Implementation of Environmental Commitments BIO-1 and GEO-2, respectively, would reduce the intensity and minimize the extent of these effects. The effect of implementing Reduced Alternative B on local groundwater conditions has been determined to be beneficial.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, engineered basins could change slightly the pattern of groundwater recharge at the site. The expected footprint of recharge basins under Alternative C would be similar to Phase 2 of Alternative B and would result in equivalent effects on geologic resources during construction and operation (Effects GEO-1, GEO-2, GEO-3, GEO-4, GEO-5, GEO-6, GEO-7, GEO-8, and GEO-9). Effects on geologic resources would be considered minor, except for the loss of soil slickspot terrain (Effect GEO-7) and the potential loss of paleontological resources discovered during construction (Effect GEO-9), which are considered adverse. Implementation of Environmental Commitments BIO-1 and GEO-2, respectively, would reduce the intensity and minimize the extent of these effects. The effect of implementing Alternative C on local groundwater conditions has been determined to be beneficial.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B. However, the expected footprint of recharge basins under Alternative D would be nearly identical to that under Alternative B and would result in equivalent effects on geologic resources during construction and operation (Effects GEO-1, GEO-2, GEO-3, GEO-4, GEO-5, GEO-6, GEO-7, GEO-8, and GEO-9). Effects on geologic resources would not be considered adverse, excluding the loss of soil slickspot terrain (Effect GEO-7) and the potential loss of paleontological resources discovered during construction (Effect GEO-9), which are considered adverse. Implementation of Environmental Commitments BIO-1 and GEO-2, respectively, would reduce the intensity and minimize the extent of these effects. The effect of Alternative D on local groundwater conditions has been determined to be beneficial.

Cumulative Effects

None of the effects described above has the potential to result in an adverse contribution to the regional cumulative effects on geologic resources in Madera County, with one potential exception. The abundance and distribution of slickspots in California have been reduced significantly; thus, losses at Madera Ranch could result in an adverse cumulative effect on this pedologic resource. Environmental Commitment BIO-1 is anticipated to protect this resource at Madera Ranch and thus not contribute to regional cumulative effects.

As Reduced Alternative B and Alternatives C and D are equivalent in scope and overall effect to Alternative B, it is anticipated that these alternatives would not contribute to cumulative effects on geologic resources.

3.8 Global Climate

Climate change refers to significant change in measures of climate (e.g., temperature, precipitation, or wind) lasting for decades or longer. Many environmental changes can contribute to climate change [changes in sun's intensity, changes in ocean circulation, deforestation, urbanization, burning fossil fuels, etc.] (Environmental Protection Agency 2010a)

Gases that trap heat in the atmosphere are often called greenhouse gases (GHG). Some GHG, such as carbon dioxide (CO_2), occur naturally and are emitted to the atmosphere through natural processes and human activities. Other GHG (e.g., fluorinated gases) are created and emitted solely through human activities. The principal GHG that enter the atmosphere because of human activities are: CO_2, methane (CH_4), nitrous oxide (N_2O), and fluorinated gasses (Environmental Protection Agency 2010a).

During the past century humans have substantially added to the amount of GHG in the atmosphere by burning fossil fuels such as coal, natural gas, oil and gasoline to power our cars, factories, utilities and appliances. The added gases, primarily CO_2 and CH_4, are enhancing the natural greenhouse effect, and likely contributing to an increase in global average temperature and related climate changes. At present, there are uncertainties associated with the science of climate change (Environmental Protection Agency 2010b).

The most notable regulation related to GHG emissions in the Proposed Action area is the California Global Warming Solutions Act of 2006, widely known as Assembly Bill 32, which requires the California Air Resources Control Board (CARB) to develop and enforce regulations for the reporting and verification of statewide GHG emissions. The CARB is directed to set a GHG emission limit, based on 1990 levels, to be achieved by 2020. The bill sets a timeline for adopting a scoping plan for achieving GHG reductions in a technologically and economically feasible manner.

3.8.1 Affected Environment

More than 20 million Californians rely on the SWP and CVP. Increases in air temperature may lead to changes in precipitation patterns, runoff timing and volume, sea level rise, and changes in the amount of irrigation water needed due to modified evapotranspiration rates. These changes may lead to impacts to California's water resources and project operations.

The Proposed Action is located in the SJVAB, which is within the jurisdiction of the SJVAPCD. The SJVAPCD has not adopted programs addressing global climate change. However, at its August 21, 2008, meeting, the governing board of the SJVAPCD took action authorizing the Air Pollution Control Officer to begin development of a Climate Change Action Plan, which would include development of guidance for considering GHG in the CEQA process; development of a carbon exchange bank for voluntary GHG reductions in the SJVAB; development of voluntary emission reduction agreements to mitigate GHG increases associated with new projects; and encouragement of the development of climate protection measures that reduce GHG emissions as well as toxic and criteria pollutants and opposition to measures that result in significant increases in toxic or criteria pollutant emissions in already affected areas.

3.8.2 Environmental Consequences

The Proposed Action's incremental increases in GHG emissions associated with off-road construction equipment would contribute to regional increases in GHG emissions and associated climate change effects. Operational effects resulting from pumping at wells and lift stations to deliver water to users also would produce GHG emissions through the combustion of propane if propane pumps are used. The assessment of climate change impacts considers each of these potential sources.

Construction Effects Assessment Methods

Construction emissions were calculated based on the type and magnitude of development that would occur during the construction period. Proposed Action–related factors used to evaluate construction climate change impacts include:

- *CO_2, CH_4, and N_2O Emissions from Construction Equipment:* Type, number of pieces, and usage for each type of construction equipment; estimated fuel usage and type of fuel (diesel, gasoline) for each type of equipment; and emission factors for each type of fuel.
- *CO_2, CH_4, and N_2O Emissions from Delivery and Haul Trucks:* Type, capacity, number of trips, haul distance, and Emfac2007 emission factors from URBEMIS 2007.
- *CO_2, CH_4, and N_2O Emissions from Grading, Excavation, and Hauling Equipment:* Type and number of pieces of equipment to be used, projected haul routes associated with soil movement, and fuel emission factors.
- *CO_2, CH_4, and N_2O Emissions from Other Mobile Sources:* Mobile source emissions associated with haul truck activities and worker commute trips were evaluated based on information provided by the project applicant.

The URBEMIS 2007 model (version 9.2.4) was used to calculate CO_2 emissions associated with construction. URBEMIS 2007 accounts for CO_2 emissions resulting from fuel use by construction equipment and worker commutes.

URBEMIS does not quantify CH_4 and N_2O emissions, although these two pollutants are emitted from construction equipment. CH_4 and N_2O emissions associated with construction emissions from off-road equipment were determined by scaling the construction CO_2 emissions predicted by URBEMIS by the ratio of CH_4/CO_2 and N_2O/CO_2 emissions expected per gallon of diesel fuel according to the California Climate Action Registry diesel fuel emission estimates (The Climate Registry 2008).

Because GHG have long atmospheric lifetimes, total GHG emissions were summed for the length of the construction period.

Operational Effects Assessment Methods

Operation emissions for the action alternatives would include both indirect mobile-source emissions and direct stationary source emissions. Emissions from mobile sources associated with operation of the alternatives would be generated by workers commuting, but because the alternatives would employ only a few workers, the emissions associated with commute trips would be negligible.

If propane engines are used, direct emissions from stationary sources would result from their operation to drive pumps installed at wells and lift stations. The primary operational emissions associated with the Proposed Action are expected to include CO_2, CH_4, and N_2O emitted as IC engine exhaust. Operational emissions of GHG were estimated using calculations based on emission factors from The Climate Registry (The Climate Registry 2008).

MID provided information on the estimated size and number of engines for wells and lift station pumps. Worst-case engine hp requirements were used to estimate emissions for the purposes of this analysis to ensure that all potentially adverse effects are disclosed. However, actual or average emissions likely will be substantially lower than the worst-case emissions scenario.

Alternative A—No Action

Under the No Action Alternative, changes in the GHG emissions. However, the future conditions would likely change to support agricultural activities or water banking activities. Thus, additional climate change effects could occur based on future land use; the amount and type of climate change effects would depend on future practices.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect CC-1: Increased GHG Emissions during Construction Increases in GHG in the atmosphere may result in climate changes. California relies on snowpack for summer streamflows to provide energy, municipal water, watershed health, and irrigation. A potential rise in sea levels could threaten California's coastal communities. Reduced snowpack, changes in the timing of streamflows, extreme or unusual weather events, rising sea levels, increased occurrences of vector-borne diseases, and effects on crop health could significantly affect the environment in Madera County. Construction of the Proposed Action would result in the direct emissions of GHG through the use of petroleum fuels and indirect emissions through the use of electrical power.

Section 2, ―Alternatives," presents measures that would be implemented as part of the Proposed Action to reduce dust (Environmental Commitment AQ-1) and vehicle exhaust emissions (Environmental Commitment AQ-2), and some of these measures also would help reduce GHG emissions.

The Proposed Action's incremental increases in GHG emissions associated with off-road construction equipment would contribute to regional increases in GHG emissions and associated climate change effects. This analysis presents the quantity of GHGs that would be emitted with implementation of the Proposed Action in the context of the total GHG emissions in California. The GHG mass calculations were performed using The Climate Registry's emissions factors for diesel fuel for construction equipment and were converted into units of carbon dioxide equivalents (CO_2e) using the IPCC's Second Assessment Report global warming potential values. Table 3-19 provides a summary of the estimated indirect and direct GHG emissions from construction.

Table 3-19 Maximum Construction Emissions for the Proposed Action (metric tons)

Emission Source	CO_2	CH_4	N_2O	CO_2e
On-site heavy equipment, including fugitive dust and worker trips				
Phase 1	4,884.6	0.3	0.1	4,929.3
Phase 2 (grading)	3,683.9	0.2	0.1	3,717.6
Worker Trips—Fresno	390.2	0.0	0.0	393.8
Worker Trips—Madera	38.0	0.0	0.0	38.3
Worker Trips—Chowchilla/Firebaugh	18.7	0.0	0.0	18.9
Haul Trucks	875.9	0.1	0.0	883.9
Total	**9,891.4**	**0.6**	**0.3**	**9,981.8**

The total estimated CO_2e emissions during construction would be approximately 9,982 metric tons. This is approximately 0.002% of the CO_2e emissions for California in 2004 (California Air Resources Board 2007). These emissions would not continue past the Proposed Action completion date. As such, this would not result in a substantial change in GHG emissions, and there would be no adverse effect.

Effect CC-2: Increase in GHG Emissions as a Result of Operation and Maintenance

Operation of the Proposed Action would require pumping at wells and lift stations to deliver water to users. For the purpose of this analysis, MID conservatively has assumed that all new pumps could be propane-powered. Use of electric pumps in place of propane pumps would reduce GHG emissions from operations. Propane-fueled IC engines that exceed 50 hp would require a permit from the SJVAPCD. Because the electric pumps at existing wellhead locations are not expected to contribute any operational emissions as a result of this action, they are not addressed in this analysis, which focuses instead on the worst-case scenario, the potential emissions associated with cycling and operation of the propane-fueled IC (catalytic-controlled) engines.

The engines could be used up to 24 hours per day and up to a total operating time of 2,880 hours per year. The emission estimate uses the worst-case scenario of 102 engines with a combined total of 7,385 hp. It was assumed that the pumps would consume 8,500 British thermal units per horsepower-hour (btu/hp-hr) (Israelson 1962). Table 3-20 provides a summary of the estimated direct GHG emissions from operation.

Table 3-20 Alternative B–Related Emissions from Operations (tons per year)

	CO_2	CH_4	N_2O	CO_2e
Controlled emissions from IC engines at wells and lifts/stations	11,402.1	0.02	0.07	11,425.4

Notes:
Estimate assumes a combined total of 7,385 hp.
Estimate assumes engine operating time of 2,880 hours per year.
Propane fuel consumption estimated at 8,500 btu/hp-hr (Israelson 1962). Emission factors for propane based on The Climate Registry General Reporting Protocol (The Climate Registry 2008).

This emission estimate is based on a worst-case scenario of all engines operating on propane fuel and pessimistic assumptions for the maximum number of engines required. In the event that a combination of propane- and electric-powered engines is used or fewer engines are required, the emissions would be reduced.

The annual estimated operational increase in CO_2e emissions under the Proposed Action would be approximately 11,425 metric tons. This is approximately 0.002% of the projected CO_2e emissions for California in 2004 (California Air Resources Board 2007).

The Proposed Action's contribution to global climate change is small compared to the total California emissions, but operation of propane-powered pumps over the life of the WSEP could result in an adverse effect. Implementation of Environmental Commitments AQ-3: Use Electric Pumps would reduce the severity of this effect.

Effect CC-3: Secondary Emissions at Power Plants Electricity and natural gas usage by the pumps and any additional facilities to be constructed or improved as a result of the Proposed Action is expected to be minimal. Use of electricity instead of propane for the pumps is expected to decrease GHG emissions from pumping activities. Maintenance activities of existing facilities, including facility upkeep and operation, would not change as a result of the Proposed Action. Additionally, the maintenance associated with new facilities such as ponds would not result in noticeable changes in emissions. Table 3-21 summarizes electricity-related GHG emissions associated with project operations. These emissions would not be considered an adverse effect.

Table 3-21 Electricity-Related GHG Emissions Operations, Alternatives B–D (metric tons per year)

	Total Electricity Usage (kWh/year)	CO_2 Emissions	CH_4 Emissions	N_2O Emissions	CO_2e Emissions
kWh Off peak	1,738,613	385.76	0.0238	0.0064	388.2
kWh Partial peak	1,096,082	243.20	0.0150	0.0040	244.8
kWh On peak	944,898	209.65	0.0129	0.0035	211.0
kWh Off peak	180,986	40.16	0.0025	0.0007	40.4
kWh Partial peak	180,986	40.16	0.0025	0.0007	40.4
Total	**4,141,565**	**919**	**0**	**0**	**925**

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used and a reduced number of basins would be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. The construction activities and operational needs under Reduced Alternative B would be similar to Alternative B and would result in similar effects on climate change. Consequently, GHG emissions would be similar to those described under Alternative B.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge, and ponds would be constructed instead. The construction activities and operational needs under Alternative C would be similar to Alternative B and would result in similar effects on climate change. Consequently, GHG emissions would be similar to those described under Alternative B because recharge ponds would be constructed under this alternative.

Effect CC-1: Increased GHG Emissions during Construction Construction activities under Alternative C would be similar to those under Alternative B. The total estimated CO_2e emissions during construction are estimated to be approximately 9,982 metric tons (Table 3-19). Consequently, the effect on climate change from construction activities is considered similar to the effect under Alternative B. These emissions would be considered an adverse effect. Implementation of Environmental Commitments AQ-1, AQ-2, and AQ-3 would reduce the intensity of this effect.

Effect CC-2: Increase in GHG Emissions as a Result of Operation and Maintenance Operational activities under Alternative C would be similar to those under Alternative B. The annual estimated operational increase in CO2e emissions under Alternative C would therefore be approximately 11,425 metric tons (Table 3-20). Consequently, the effect on climate change from operational activities is considered equivalent to that under Alternative B. These emissions would be considered an adverse effect. Implementation of Environmental Commitment AQ3: Use Electric Pumps would reduce the intensity of this effect.

Effect CC-3: Secondary Emissions at Power Plants Electricity and natural gas usage required by the pumps and any additional facilities to be constructed or improved as a result of Alternative C is expected to be minimal. Use of electricity instead of propane for the pumps is expected to decrease GHG emissions from pumping activities. Maintenance activities, including facility upkeep and operation, do not change as a result of this alternative. Table 3-21 summarizes electricity-related GHG emissions associated with project operations. These emissions would not be considered an adverse effect.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D would result in an increase in GHG during construction due to additional grading and reshaping of the off-site portions of GF Canal. These effects would be larger than the reduction in air quality effects associated with fewer Section 8 canal improvements and elimination of the 24.2 lateral improvements.

Effect CC-1: Increased GHG Emissions during Construction Construction activities under Alternative D are summarized in Table 3-22.

Table 3-22 Alternative D–Related Emissions from Construction (metric tons)

Emission Source	CO_2	CH_4	N_2O	CO_2e
On-site heavy equipment, including fugitive dust and worker trips				
Phase 1	6,240.9	0.4	0.2	6,297.9
Phase 2 (grading)	3,683.9	0.2	0.1	3,717.6
Worker Trips—Fresno	390.2	0.0	0.0	393.8
Worker Trips—Madera	38.0	0.0	0.0	38.3
Worker Trips—Chowchilla/Firebaugh	18.7	0.0	0.0	18.9
Haul Trucks	875.9	0.1	0.0	883.9
Total	**11,247.6**	**0.6**	**0.3**	**11,350.4**

The total estimated CO_2e emissions during construction therefore are estimated to be approximately 11,350 metric tons. Consequently, the effect on climate change from construction activities is considered equivalent to that which would occur under Alternative B. These emissions would be considered an adverse effect. Implementation of Environmental Commitments AQ-1 and AQ-2 would reduce the intensity of this effect.

Effect CC-2: Increase in GHG Emissions as a Result of Operation and Maintenance Operational activities under Alternative D would be similar to those under Alternative B. The annual estimated operational increase in CO_2e emissions under Alternative D therefore would be approximately 11,425 metric tons. Consequently, the effect on climate change from operational activities is considered equivalent to that under Alternative B. These emissions would be considered an adverse effect. Implementation of Environmental Commitments AQ-1, AQ-2, and AQ-3 would reduce the intensity of this effect.

Effect CC-3: Secondary Emissions at Power Plants Electricity and natural gas usage required by the pumps and any additional facilities to be constructed or improved as a result of Alternative D is expected to be minimal. Use of electricity instead of propane for the pumps is expected to decrease GHG emissions from pumping activities. Maintenance activities, including facility upkeep and operation, do not change as a result of implementing this alternative. Table 3-21 summarizes electricity-related GHG emissions associated with project operations. These emissions would not be considered an adverse effect.

Cumulative Effects

Climate change is a global problem, and GHG are global pollutants. As such, impacts of the Proposed Action and its alternatives on climate change (Effects CC-1 to CC-3) have been evaluated from a cumulative perspective. Although emissions resulting from the Proposed Action and its alternatives may not be significant on a project level, the combination of emissions from many sources results in substantial effects on climate change. Consequently, emissions generated from the Proposed Action and its alternatives are considered to have adverse effects on climate change as discussed above.

Table 3-23 provides a summary of the estimated GHG emissions from construction and operation of the Proposed Action. These emissions were calculated for construction and operational activities under Alternatives B and C, as Alternatives B and C are nearly identical in scope and design. Thus, the construction activities and operational needs under Alternatives B and C would be similar.

Table 3-23 Alternative B/C–Related Emissions from Construction and Operations (tons per year)

	CO_2	**CH_4**	**N_2O**	**CO_2e**
Construction	9,401.0	0.3	0.4	9,525.7
Operation	11,402.1	0.02	0.07	11,425.4
Total	**20,803.1**	**0.32**	**0.47**	**20,951.1**

Reduced Alternative B would result in less construction activity and less emissions than Alternative B. In addition, Table 3-24 summarizes GHG emissions from construction and operation of the Proposed Action under Alternative D.

Table 3-24 Alternative D–Related Emissions from Construction and Operations (tons per year)

	CO_2	CH_4	N_2O	CO_2e
Construction	8,395.3	0.5	0.2	8,472.1
Operation	11,402.1	0.02	0.07	11,425.4
Total	**19,797.4**	**0.5**	**0.3**	**19,897.5**

The total estimated CO_2e emissions during construction and operation of the Proposed Action would be approximately 19,898 metric tons. This is approximately 0.004% of the CO_2e emissions for California in 2004 (California Air Resources Board 2007). Construction emissions would not continue past the Proposed Action completion date of 2010, and Environmental Commitments AQ-1 and AQ-2 would reduce the intensity of these effects. Operational emissions are a result of using propane pumps. Environmental Commitment AQ-3 would reduce the intensity of this effect. As such, the Proposed Action would not make a considerable contribution to climate change effects.

3.9 Growth-inducing Effects

Under authority of NEPA, CEQ Regulations require EISs to consider the potential indirect impacts of a proposed action. The indirect effects of an action are those that occur later in time or farther away in distance, but are still reasonably foreseeable, and “may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate” (40 CFR 1508.8[b]). Specifically, this evaluation of potential growth-inducing impacts addresses whether the project would directly or indirectly: foster economic, population, or housing growth; remove obstacles to growth; increase population growth that would tax community service facilities; or encourage or facilitate other activities that cause significant environmental effects.

Madera County's General Plan and California Department of Finance data sets were consulted for information related to current and future land use, population statistics, and planned growth rates for Madera County. In addition, both the GFWD and MID have developed groundwater management plans to evaluate the availability of groundwater resources to support current and future demands. The City of Madera has finalized its urban water management plan prepared pursuant to state law that documents how the available water supply would accommodate planned growth. Additionally, both the County and the City of Madera were consulted to determine whether projects approved and in process would be facilitated through the availability of M&I banking capacity at Madera Ranch.

The *California Water Plan* (California Department of Water Resources 2005), the *Critical Water Shortage Contingency Plan* (California Department of Water Resources 2000a), *Preparing for California's Next Drought*, *DWR Drought Report* (California Department of Water Resources 2000b), and *Integrated Regional Water Management Plan* (Madera County 2008) were consulted for data on statewide and local water needs, growth, and current and anticipated water shortages.

MID's budget for allocating banking capacity to local M&I users under the Proposed Action and alternatives is up to 10,000 AF/year, while MID could recover up to 45,000 AF/year for its agricultural users. It is important to note that the WSEP is intended to help offset dry or below normal water years, and water recovery for M&I uses is not expected to happen in wet or above normal years. It is reasonable to assume that there would be a net banking in wet years and a net recovery in dry years. As water year types vary, it is not expected that the WSEP would provide firm, or consistent, water supplies to those using the bank. Rather, the WSEP would provide greater water supply reliability in dry or below normal water year types. It would not increase the total amount of water supply available to any users.

Water supply by itself does not drive growth. Development at the local level is guided by many considerations, among them the availability of the water supply. Cities and counties regulate land uses by adopting general plans, zoning, and measures for the control of local growth. However, economic forces largely govern the rate and location of growth.

At the same time, economic and population growth depend on adequate water supplies. A wide range of wholesale and retail institutions plan for and manage water supply to meet current and future demands. It is conceivable that water banked at Madera Ranch could be used to improve water supply reliability or expand water supplies to users in the San Joaquin Valley and Southern California. However, MID's business plan only allows for the use of 10,000 AF/year in support of M&I projects and only within Madera County.

3.9.1 Affected Environment

California is a rapidly growing state with a 2009 population of 37 million people (U.S. Census Bureau-Last Revised: Thursday, 04-Nov-2010). The population is expected to rise to nearly 50 million by 2025 (California Department of Finance 2007).

Locally, the population of Madera County is estimated to have increased from 123,109 in 1991 to 148,632 in 2009 (U.S. Census Bureau-Last Revised: Thursday, 04-Nov-2010). The population of Madera County is estimated to increase to 212,874 by 2020 (California Department of Finance 2007).

Water use in Madera County in 2006 was 1.2 million AF, with approximately 97% (1.17 million AF) applied for agricultural purposes. Within the valley floor area of Madera County, groundwater accounted for approximately 75% of the total agricultural water use. Additionally, all urban and rural water is supplied by groundwater sources. The total county water demand is expected to be about 1.3 million AF/year by 2030, an increase of about 100,000 AF of water, most of which is attributed to growing urban and rural demand. Current overdraft is approximately 100,000 AF and is expected to rise to 155,000 AF if no action is taken in the county (Madera County 2008).

Development has proceeded in Madera County despite the existing overdraft condition. To date, the presence or absence of available groundwater has not been an obstacle to growth. With the preparation of the *Integrated Regional Water Management Plan* the County may revisit its development approval conditions and is looking seriously at a variety of options to resolve the overdraft problem. One option that may be considered is the use of Madera Ranch.

Current and Planned Development

Several residential and commercial developments are currently approved or in a discretionary permit process with the County. These projects have existing water supply rights that could utilize the water bank M&I allocation (Table 3-25). Within Madera County, there is already 7,455 AF/year of existing water supply for planned development that could potentially be banked under the M&I allocation of the alternatives. An additional 12,000 AF/year of existing water supply that could potentially utilize the bank for future development projects has also been identified. Thus, 19,455 AF/year of existing, known water supply identified for use in future land use development have been identified within Madera County. This represents almost double the amount of M&I shares (with one share equaling one AF of water) available at Madera Ranch under the proposed action and alternatives.

Additionally, many potential development projects are also identified in the *Integrated Regional Water Management Plan*; these are more speculative and water supplies for these potential projects have not yet been identified. The source of water for these projects would likely need to be groundwater or out-of-county sources. All of these projects would proceed only after County approvals and after obtaining a firm water supply, which is in no way dependent on the WSEP.

Table 3-25 Known Proposed Future Development in Madera County, Water Supply, and Potential Participants

Development	Total Project Acreage	Residential Units	Commercial/ Industrial Acreage	Status	Total af/ year (if known)	Water Supply Secured Elsewhere	Water Supply Source	Back up Dry Year Storage Needed	Potential Water Bank Participant	Potential Banked at Madera Ranch (af)
Gateway Village	2,392	6,455	185.6	Approved	6,374	Yes	Surface Water Groundwater	Yes	Yes	2,170
North Fork Village—North	2,238	2,522	82.3	Final EIR Pending	1,355	Yes	Unknown	Possibly	Unknown	1,355
Gunner Ranch West	1,135	3,014	209	Plan Pending	–	?	Unknown	Unknown	Unknown	
North Fork Village—Central Green	793	1,646	n/a	Supplemental EIR Pending	–	?	Unknown	Unknown	Unlikely	
Tesoro Viejo	1,574	4,600	n/a	Draft EIR Pending	4,810	Yes	Surface Water & Reclaimed	Possibly	Yes	3,930
Jim Cobb	350	350	60	Application Pending	–	?	Unknown	Unknown	Unlikely	
Dunmore Homes	368	2,064	n/a	Application Pending	–	?	Unknown	Unknown	Unknown	
City of Madera—Existing Homes	n/a	n/a	n/a	Existing Homes	–	?	Groundwater	Unknown	Yes	2,000
City of Madera—New Growth	500–1,000	300–400	50	Various Applications	–		Unknown	Unknown	Yes	1,000
Developer A	1,000–1,500	600	Unknown	Various Applications	1,000–1,200	Yes	Transfers	Yes	Yes	1,000
Developer B	500–1,000	500–1,000	Unknown	Application Pending	500–1,000	Yes	Transfers	Yes	Yes	1,000
Developer C	3,000	7,000	Unknown	Application Pending	7,000	Yes	Transfers	Yes	Yes	7,000
Total										**19,455**

Notes: Developers A–C are not named because final agreements have not been signed.

3.9.2 Environmental Consequences

The effect of MID water banking at Madera Ranch would be to increase the reliability and certainty of water supplies for current users with existing water rights or entitlements. The Proposed Action and alternatives do not include an application to appropriate water, would not involve water transfers, and would not create new water supplies that could be dedicated to urban development. The Proposed Action and alternatives are not anticipated to result in additional employment or demand for residential development within Madera County and therefore would not induce growth through increased economic activity.

Effect GI-1: Inducement of Growth due to Municipal and Industrial Participation in Water Bank

Between the currently identified planned projects and the current overdraft situation, the full 10,000 AF/year of non-MID M&I banking capacity is very likely, if not certain, to be fully utilized. Only participants with an existing water supply would be allowed to participate in the Bank. The banking of this water would not change the overall amount of water available to these M&I users, but does improve the reliability of the supply since the banking capacity provided by the WSEP helps M&I users manage their supplies. This firm supply would be applied to the planned growth regardless of implementation of the WSEP. The WSEP would therefore not cause growth, but removes an obstacle to growth because the increased reliability could make development easier or more attractive.

This growth could result in the conversion of agricultural and other open land to urban. It would be extremely speculative to identify specific areas where growth could occur or the indirect effects on specific community service facilities. The impacts of this growth, if any, would be (and in some cases have been) analyzed either in general plan EIRs for the local jurisdictions or in project-level CEQA compliance documents.

3.10 Hazards, Public Health, and Safety

This section describes the existing environmental setting for analyzing hazards and public health issues potentially affected by the proposed alternatives. The issues include hazardous materials, mosquitoes, drowning, and wildland fire.

3.10.1 Affected Environment

Historical and current agricultural, commercial, and industrial activities associated with the Madera Ranch site and adjoining area have been associated with hazardous materials usage, storage, and disposal. An environmental site assessment was conducted for the area, including Madera Ranch and a greater study area with a radius of five miles. In addition, a limited phase-2 site assessment was completed (TRC 1999, 2002).

Soil Contamination

There are no residences within one mile of known soil contamination and no schools in the vicinity of Madera Ranch. A site assessment was conducted in September 1999 and again in July 2002. This assessment included reconnaissance of Madera Ranch, review of regulatory databases, interviews of property owners and regulatory agency personnel, and limited sampling of groundwater (TRC 1999, 2002). The initial environmental site assessment found no evidence of on-site contamination. However, some past and present on-site fuel storage may have resulted in soil contamination in the immediate area of the storage sites.

Records of three on-site underground storage tanks (UST) were found. The records disclosed that the UST had been removed under the oversight of County Environmental Health Department officials. For all three UST removals, closure letters were issued indicating that no further action was required. The only contamination found through observations during UST removal and limited soil sampling was trace amounts of toluene at one of the UST sites (TRC 1999).

Several of the irrigation wells in Sections 1 and 13 of the Madera Ranch property have been fitted with diesel motors and supporting aboveground storage tanks (AST). These 1,500-gallon diesel AST do not have secondary containment but recently have been equipped with drip collection pans. The soil in the region of the motor and AST pads was stained (TRC 1999). Although stained soil was observed at these AST locations, significant contamination as a result of AST operation is not likely.

Mosquito-Borne Diseases

In addition to being a nuisance, mosquitoes can act as disease-carrying vectors. All species of mosquitoes require standing water to complete their growth cycle. Mosquitoes reproduce year-round, but reproduction is substantially diminished during the cool winter season, roughly October through April, and mosquito suppression activities in Madera County typically begin in March (Dillahunti pers. comm.). Water quality also affects mosquito reproduction. Generally, poor-quality water (water with limited circulation, high temperature, and high organic content) produces greater numbers of mosquitoes than high-quality water (water with high circulation, low temperature, and low organic content) (Collins and Resh 1989). In addition, irrigation and flooding practices may influence the level of mosquito production associated with a water body. Typically, water bodies with water levels that slowly increase or recede produce greater numbers of mosquitoes than water bodies with water levels that are stable or that rapidly fluctuate (Collins and Resh 1989).

Mosquito Species of Concern In Madera County, two species of mosquito are primary targets for suppression (Dillahunti pers. comm.). These two species, *Culex pipiens* and *C. tarsalis*, are potential vectors of encephalitis and West Nile virus. Other species of mosquitoes exist in Madera County that can cause a substantial nuisance in surrounding communities, but the *Culex* mosquito is the vector species of primary concern.

Although the West Nile virus can be transmitted by a number of mosquito species, *Culex* is the most common carrier. This disease is thought to be a seasonal epidemic that flares up in the summer and fall. West Nile virus is spread when mosquitoes that feed on infected birds bite humans and other animals (U.S. Department of Health and Human Services 2005).

The encephalitis mosquito (*C. tarsalis*) breeds in almost any freshwater pond. Birds appear to be the primary blood-meal hosts of this species, but the insect also will feed on domestic animals and humans (Bohart and Washino 1978). This species is the primary carrier in California of western equine encephalitis, St. Louis encephalitis, and California encephalitis and is considered a significant disease vector of concern in the state.

The house mosquito (*C. pipiens*) usually breeds in waters with a high organic material content (Bohart and Washino 1978). This species often is identified by its characteristic buzzing near its host's ear. Although the primary blood-meal host is birds, the house mosquito also can seek out humans. The house mosquito can be a vector of St. Louis encephalitis.

Mosquito Concerns at Madera Ranch Potential mosquito habitat exists on the Madera Ranch site. Natural water features, including swales and vernal pools, are potential mosquito breeding sites. In addition, agricultural ditches and canals and irrigated cropland are potential mosquito breeding sites. Orchards and vineyards surrounding the Madera Ranch site have been identified as breeding areas (Dillahunti pers. comm.).

3.10.2 Environmental Consequences

Hazardous Materials

Effects related to hazardous materials include the mixing of known contaminated soil or groundwater with imported water. Reconnaissance of the site, review of regulatory databases, and interviews of property owners and regulatory agency personnel contained in the initial site assessment (TRC 1999, 2002) form the basis for understanding potential hazardous materials effects. Limited confirmatory sampling, including sampling of agricultural groundwater wells and agricultural soils, was conducted to identify existing and potential groundwater concerns with regard to the mobilization and transport of agricultural nonpoint-source pesticides. California Department of Pesticide Regulation's existing database of groundwater management zones, which was developed using a statistical approach to determine areas of groundwater vulnerability, was reviewed to identify potential areas of pesticide mobilization concerns.

Health Hazards

The creation, removal, and/or management of habitat types, including irrigated agriculture, could increase or decrease the amount of potential breeding habitat for mosquitoes. Management and design of recharge facilities could substantially affect mosquitoes' breeding success. Breeding conditions and abatement requirements were evaluated based on mosquito ecology and control literature, communication with MCMAVCD staff, and the design and operational management specifications of each alternative.

Safety Hazards

Potential physical safety hazards, including drowning and wildland fire, were reviewed based on various risk factors, such as proximity to human populations, ease of public access, and public rights-of way. Potential physical hazards from dam failure were evaluated quantitatively by comparing recharge basin design to the DWR's Division of Safety of Dams (DSOD) criteria.

Alternative A—No Action

Under the No Action Alternative, there would be no adverse effects on public health and safety. However, the future conditions would change to support agricultural activities. Potential effects would be evaluated by the County under CEQA depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Alternative B would involve the use of hazardous materials during construction and operations (e.g., fuels, lubricants, paints, coatings, pesticides). Also, the water that would be banked in the swales and/or recharge basins could support mosquitoes. Mosquito breeding success could be substantially affected by management and design of the swales or recharge basins. Alternative B could increase or decrease the amount of potential breeding habitat for mosquitoes.

Effect PHS-1: Potential Creation of a Public Hazard from Risk of Drowning Several canals would be enlarged or extended as a result of Alternative B. Maintenance ramps would provide egress at several locations along the canals, most likely near points of Madera County road crossings. Reasonable measures to prevent trespass also have been included in the design of facilities. Safety precautions, such as fencing around the entire Madera Ranch property, warning signs, and setbacks, will be taken. MID will implement Environmental Commitment PHS-1a, Implement Necessary Emergency Preparedness Plan(s), to minimize the potential for this effect. Therefore, the potential hazard of drowning represented by Effect PHS-1 is not considered adverse.

Effect PHS-2: Potential Creation of a Public Hazard from Risk of Berm Failure Recharge basins would be constructed on up to 1,000 acres under Alternative B, although individual basin cells would be on the order of five–80 acres each. These basins would be excavated, and some spoils would be used to form low berms to achieve an effective depth of up to five feet to prevent wind-induced waves from overtopping the berms. Berm heights would vary, depending on topography, but would not exceed five feet.

The DWR's DSOD has developed criteria delineating its jurisdiction over impounded surface water bodies. Because the berms would not exceed a height of five feet, they would be below the DSOD jurisdictional height limit of six feet. The nearest residence is approximately 0.75 mile away, uphill of the recharge basin locations and outside the fenced ranch perimeter. Given the topography of the area between the recharge basins and residences, water escaping in the event of berm failure would pool on land between Madera Ranch and the residence. Thus, there would be no effect.

Effect PHS-3: Potential Creation of a Public Hazard from Risk of Wildland Fire Madera Ranch is covered primarily by annual grassland. During summer months, this dry grassland could pose a fire hazard. Although dense population centers, such as the city of Madera, are physically separated from Madera Ranch by surrounding agriculture, there are several residences near the Madera Ranch site. Existing roads on Madera Ranch would be bladed on a regular basis and could act as firebreaks. The potential fire hazard to the public as a result of accidental ignition of grassland is low, and once constructed Alternative B would not result in changes in this hazard. However, a minor increase in wildfire risks could occur during construction as a result of using construction equipment in the vicinity of dry grassland. Environmental Commitments PHS-1a and PHS-1b would reduce the intensity of this hazard.

Effect PHS-4: Potential Increase in Adult Mosquito Populations Under Alternative B, water would be diverted into 700 acres of swales. Up to 1,000 acres of recharge basins also could be flooded to about three to five feet deep and would have berms with 1:1.5 to 1:2 vertical-to-horizontal slopes. Recharge basins and canals would be managed to control and eliminate emergent vegetation.

During the mosquito-breeding period of March–October, recharge basins and swales used to perform recharge generally would not contain standing water. During nonoperational periods, recharge basins and swales are expected to be fully drained approximately eight months of any given year. The size of each recharge basin cell would be about five to 80 acres, which is enough area to generate wave action from winds, which would suppress development of mosquito larvae. Waves can disrupt the ability of mosquito larvae to penetrate the surface of water and take flight, thus effectively suppressing the population.

Water in the swale areas would range in depth from several inches to four feet, and water flowing through the swales also would discourage development of mosquito larvae. During pilot testing of recharge on the property, MID observed that water percolates quickly. Typically, no standing water remained more than 24 hours after flow to the swales and basins had ceased. Thus, MID expects that mosquito production would be inhibited because during application, water levels would fluctuate rapidly as water flows through the swales and generally would not persist after flows cease. Additionally, only during a few months in spring would the timing for application of the water and the breeding season overlap.

Emergent vegetation is a critical element of mosquito breeding habitat because the vegetation is used as a structure to hold eggs and/or cover larvae. Emergent vegetation would be eliminated from the recharge basins whenever possible to further reduce the likelihood of mosquito production. However, vegetation would not be removed from the swales.

New and enlarged MID conveyances under Alternative B would convey water through the irrigation season according to the currently used schedules but would contain water more frequently because of the conveyance of water to and from the water bank. Months of operation would vary, although the conveyances would carry water primarily during the summer and fall under extraction operations and during the winter under recharge operations. Although mats of algae or other vegetation could develop in the conveyances, providing suitable habitat for mosquito production, algae growth (and control measures) would be the same as under current conditions.

It is conceivable that a net increase in mosquito production, and resulting increased public health risks, could occur; therefore, Effect PHS-4 is potentially adverse. The Environmental Commitment PHS-2 to Implement an Agreement with the MCMAVCD would reduce the intensity of adverse effects.

Effect PHS-5: Potential Exposure or Disturbance of Hazardous Materials or Wastes An initial environmental site assessment at Madera Ranch, including site reconnaissance, database review, and interviews, was conducted in September 1999 and again in July 2002. The site assessment did not identify substantial soil or groundwater contamination on or in the vicinity of

Madera Ranch related to past or present storage, handling, or disposal of hazardous materials and wastes. The initial site assessment also did not identify any significant regional groundwater contamination plume or significant Resource Conservation and Recovery Act-permitted storage facilities within a five-mile radius of the Madera Ranch site.

Although there are no substantial hazardous materials concerns in the Madera Ranch site and vicinity, surface soil contamination associated with AST in Sections 1 and 13 was identified during the site reconnaissance. This type of contamination is commonly found at similar diesel-powered pump engines, and as described above, it was determined that the contamination is limited to the immediate area of the AST. However, Sections 1 and 13 are currently used to grow grain and hay crops and would continue to be used for that purpose as part Alternative B. No recharge basins are proposed for construction in Section 1 or 13, and there are no swales in these sections that could be used for recharge. The only change proposed as part of Alternative B would be that MID would deliver surface water, when available, in lieu of pumping groundwater to irrigate the fields.

During construction and operation, the use of fuels and lubricants for construction equipment and propane pumps has the potential to accidentally release hazardous materials into the environment. To reduce this adverse effect, Environmental Commitment WQ-1b: Implement a Spill Prevention and Control Program would be implemented. Therefore, exposure or disturbance of hazardous materials or waste is not anticipated and there is no effect.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used (550 acres versus 700 acres as proposed under Alternative B) and a reduced number of basins would be constructed (323 acres versus up to 1,000 acres under Alternative B). Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. Thus, there would be no substantive differences in public health and safety effects between Alternative B and Reduced Alternative B. Reduced Alternative B would result in equivalent effects related to an increase in drowning risks at new canals and ditches, berm failure, wildland fires during construction, mosquito production at the recharge basins, and release or disturbance of hazardous materials (Effects PHS-1, PHS-2, PHS-3, PHS-4, and PHS-5). Adverse effects resulting from fire risk (Effect PHS-3) would be mitigated as described under Alternative B (Environmental Commitment PHS-1a and 1b). Although Reduced Alternative B would use fewer swales and limits the number of recharge basins, it still provides similar open-water habitats and would result in similar potential effects regarding mosquito breeding (Effect PHS-4) that would be minimized as described under Alternative B (Environmental Commitment PHS-2).

Alternative C—Water Banking Outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, there would be no substantive differences in public health and safety effects between Alternatives B and C. Alternative C would result in equivalent effects related to an increase in drowning risks at new canals and ditches, berm failure, wildland fires during construction, mosquito production at the recharge basins, and release or disturbance of hazardous materials (Effects PHS-1, PHS-2, PHS-3, PHS-4, and PHS-5). Adverse effects resulting from fire risk (Effect PHS-3) would be mitigated as described under Alternative B (Environmental Commitment PHS-1a and 1b). Alternative C provides similar open-water habitats and would result in similar potential effects regarding mosquito breeding (Effect PHS-4) that would be minimized as described under Alternative B (Environmental Commitment PHS-2).

Alternative D—Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B and lift station would be built in different locations than proposed under Alternative B. Thus, there would be no substantive differences in public health and safety effects between Alternatives B and D. Alternative D would result in equivalent effects (Effects PHS-1, PHS-2, PHS-3, PHS-4, and PHS-5). Adverse effects resulting from fire risk still would be present (Effect PHS-3) and would be minimized as described under Alternative B (Environmental Commitment PHS-1a and 1b). Alternative D provides similar open-water habitats as described under Alternative B and would result in equivalent potential effects regarding mosquito breeding (Effect PHS-4) and would be mitigated as described under Alternative B (Environmental Commitment PHS-2).

Cumulative Effects

Effects related to fire and increased mosquito production could have cumulative impacts in Madera County. Development of emergency preparedness plans (Measure PHS-1a) and compliance with local fire district requirements (Measure PHS-1a) would negate any cumulative fire risk. Likewise, completion of an implementation agreement with the MCMAVCD (Measure PHS-2) would eliminate the risk of any potential contribution to regional increases in adult mosquitoes.

As Reduced Alternative B and Alternatives C and D are identical to Alternative B in scope and effect, it is not anticipated that these alternatives would not contribute to cumulative effects on public health and safety as well.

3.11 Indian Trust Assets

ITA are legal interests in property held in trust by the United States for federally recognized Indian tribes or individual Indians. An Indian trust has three components: (1) the trustee, (2) the beneficiary, and (3) the trust asset. ITA can include land, minerals, federally reserved hunting and fishing rights, federally reserved water rights, and instream flows associated with trust land. Beneficiaries of the Indian trust relationship are federally recognized Indian tribes with trust land; the United States is the trustee. By definition, ITA cannot be sold, leased, or otherwise encumbered without approval of the United States. The characterization and application of the United States trust relationship have been defined by case law that interprets Congressional acts, executive orders, and historical treaty provisions.

Consistent with President William J. Clinton's 1994 memorandum, Government-to-Government Relations with Native American Tribal Governments, Reclamation assesses the effect of its programs on tribal trust resources and federally recognized tribal governments. Reclamation is tasked to actively engage federally recognized tribal governments and consult with such tribes on a government-to-government level (59 FR 1994) when its actions affect ITA.

The U.S. Department of the Interior Departmental Manual Part 512.2 ascribes the responsibility for ensuring protection of ITA to the heads of federal bureaus and offices (U.S. Department of the Interior 1995). Part 512, Chapter 2, of the Departmental Manual states that it is the policy of the DOI to recognize and fulfill its legal obligations to identify, protect, and conserve the trust resources of federally recognized Indian tribes and tribal members. All Federal bureaus are responsible for, among other things, identifying any effect of their plans, projects, programs or activities on ITA; ensuring that potential effects are explicitly addressed in planning, decision, and operational documents; and consulting with recognized tribes who may be affected by the WSEP.

Consistent with this, Reclamation's Indian trust policy states that Reclamation will carry out its activities in a manner that protects ITA and avoids adverse effects when possible, or provides appropriate mitigation or compensation when it is not. To carry out this policy, Reclamation incorporated procedures into its NEPA compliance procedures to require evaluation of the potential effects of its proposed actions on trust assets (Bureau of Reclamation 1993). Reclamation is responsible for assessing whether the alternatives have the potential to affect ITA. Reclamation will comply with procedures contained in Departmental Manual Part 512.2, guidelines, which protect ITA.

3.11.1 Affected Environment

The nearest ITA to the WSEP is the Table Mountain Rancheria which is located approximately 28 miles east-northeast of the Proposed Action area.

3.11.2 Environmental Consequences

No tribes possess legal property interests held in trust by the United States in the area affected by any of the alternatives. Thus, none of the alternatives would affect ITA.

3.12 Land Use

This section describes the existing and planned land uses for the areas potentially affected by the proposed alternatives.

The affected environment was determined by analyzing various documents, examining aerial photographs of the site, and holding discussions with MID and County Planning Department staff. Future planned uses for the vicinity were identified by examination of the County General Plan and County zoning maps. The determination of effects was made by comparing the existing and planned environmental setting for land use with how each resource would be affected by implementation of the alternatives.

The sources of information used in this section include:

- Madera County General Plan Background Report (Madera County 1995a),
- Madera County General Plan Policy Document (Madera County 1995b), and
- Madera County General Plan Land Use Diagram (Madera County 1995c).

3.12.1 Affected Environment

Madera Ranch is located in western Madera County, several miles from the city of Madera and the unincorporated community of Firebaugh. The site is situated in a rural agricultural area under the jurisdiction of the County. No other established communities are located in the vicinity of Madera Ranch.

As shown in Figure 3-7, most of Madera Ranch consists of grasslands, with smaller portions of the site in agricultural production. Agricultural land uses include a mix of field crops, hay and grain crops, and a small portion in vineyard production. In addition to agricultural land uses, Madera Ranch contains numerous on-site access roads, irrigation wells, various related utilities, canals, drainage ditches, and a shop/storage area.

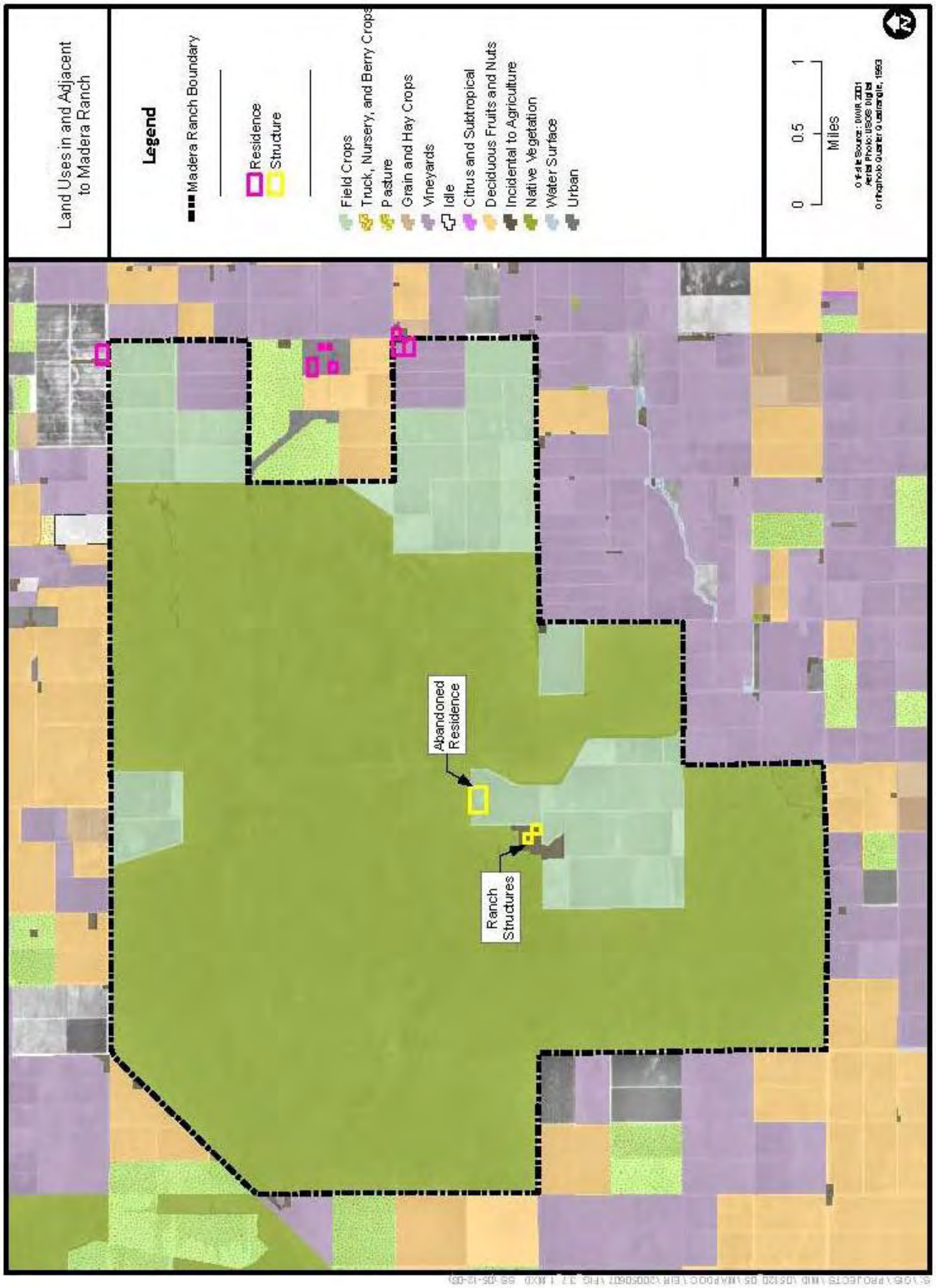


Figure 3-7 Land Uses in and Adjacent to Madera Ranch

3.12.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative there would be no adverse effects on land use. However, the future conditions could change to support agricultural activities. Potential effects would be evaluated by the County under CEQA depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Madera Ranch is located in western Madera County and is generally bounded by Avenue 7, Avenue 12, and Road 21. The site is located several miles from the city of Madera and the unincorporated community of Firebaugh. No other established communities are in the vicinity of Madera Ranch. Because the proposed water bank is located at a distance from both of these communities and would retain traffic flow along Avenue 7, Avenue 12, and Road 21, it would not physically divide an established community.

There is no habitat conservation plan that applies to the Madera Ranch site; therefore, there would be no effects associated with potential conflict with an applicable habitat conservation plan.

Effect LU-1: Conflict with Applicable Land Use Plans, Policies, or Regulations, Including Land Use Designations and Zoning Ordinances Madera Ranch is designated by the General Plan land use diagram as AE (agricultural exclusive). The site also is zoned for agricultural rural exclusive (40-acre minimum). For the effect to be minor, future proposed land uses must be compatible with current agricultural land use designations. The County Planning Department previously determined that development of a groundwater bank on the Madera Ranch site would not conflict with the AE designation (Merchen pers. comm.). In addition, grazing and agricultural land use would continue on most of the ranch, along with some row crop production. While some of the modifications would directly remove a small portion of farmland from production, these modifications would be consistent with continued agricultural production because they would enhance agricultural production by providing improved water storage and supply for agricultural irrigation. Because Alternative B would not conflict with applicable land use plans, policies, or regulations, Effect LU-1 would have no effect.

Effect LU-2: Land Use/Operational Conflicts between Existing and Proposed Land Uses As discussed under Effect LU-1, modifications to the Madera Ranch site would be compatible with agricultural land uses at Madera Ranch. Construction activities might disrupt agricultural operations at Madera Ranch, but these disruptions would be only temporary and would not result in permanent conflict with agricultural land uses. In addition, the resulting changes would not fragment agricultural land or result in modifications that would indirectly preclude agricultural land uses. As mentioned above, the proposed facilities (recharge basins, canals, and ditches) would be similar to existing structures that do not conflict with agricultural uses, but rather facilitate agricultural production by providing improved water supply and storage for agricultural irrigation. Effect LU-2 is not considered adverse because implementation of Alternative B would not conflict with existing or proposed land uses.

Effect LU-3: Conflict with Recreational Land Uses No recreational areas are located in or near the Madera Ranch site nor would Alternative B affect recreational activities. The purpose of Alternative B is to enhance water supply services, and it would not affect recreation or increase the need for recreational services. Alternative B would not conflict with recreational land uses. Effect LU-3 would result in no effect.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used and a reduced number of ponds would be constructed. This would not result in any differences from what was described above for Alternative B relative to land use effects. Reduced Alternative B would not conflict with applicable land use plans, policies, or regulations; recreational land uses; or existing or proposed land uses (Effects LU-1, LU-2 and LU-3). Similar to Alternative B, under Reduced Alternative B, Effects LU-1 and LU-3 would result in no effect, and Effect LU-2 is not considered adverse.

Alternative C—Water Banking Outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, there would be no differences in land use between Alternatives B and C. Alternative C would result in equivalent effects on land use (Effects LU-1, LU-2, and LU-3) and would not conflict with applicable land use plans, policies, or regulations; or recreation or other land uses. Identified effects on land use related to minor disruptions of agriculture are not considered adverse (Effect LU-2).

Alternative D—Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that recharge is achieved using engineered recharge basins in lieu of the natural swales that occur on the site, and water would be delivered to and from the site using the GF Canal. Thus, there would be no differences in land use between Alternatives B and D. Alternative D would result in equivalent effects on land use (Effects LU-1, LU-2, and LU-3) and would not conflict with applicable land use plans, policies, or regulations; or recreation or other land uses. Identified effects on land use related to minor disruptions of agriculture during construction are not considered adverse (Effect LU-2).

Cumulative Effects

The alternatives would not result in conflicts with existing or proposed land uses in the Madera Ranch area. As such, Alternative B would not result in a considerable contribution to cumulative effects. As Reduced Alternative B and Alternatives C and D are equivalent in scope and overall effect as Alternative B, these alternatives would not result in cumulative effects on land use.

3.13 Noise

This section describes potential temporary and permanent increases to noise levels resulting from the construction and operation of the WSEP.

Potential sources of noise associated with the WSEP are:

- activities associated with construction of the canals and the recharge basins,
- drilling of the recovery wells,

- operation of the well pumps, and
- operation of the engines at the lift stations.

Sound levels produced by these various sources are based on data from standard references, previous studies, and equipment manufacturers' data. Projected sound levels from these sources then are estimated using a point-source attenuation model. With this model, noise from the source is assumed to attenuate at a rate of 6 decibels for each doubling of distance. To determine potential noise effects, the distances needed for noise to attenuate to County noise-level standards of 45 dBA (nighttime) and 50 dBA (daytime) are assessed for each source.

A brief discussion of common noise terminology and descriptors used in this section follows.

- *Sound:* A vibratory disturbance created by a vibrating object that, when transmitted by pressure waves through a medium such as air, can be detected by a receiving mechanism like human ears or a microphone.
- *Noise:* Sound that is loud, unpleasant, unexpected, or otherwise undesirable.
- *Decibel (dB):* A measure of sound or vibration amplitude on a logarithmic scale that indicates the squared ratio of sound pressure or vibration velocity root-mean-squared amplitude to a reference sound pressure or vibration amplitude. For sound, the reference pressure is 20 micropascals.
- *A-weighted decibel (dBA):* An overall frequency-weighted sound level in decibels that approximates the frequency response of the human ear.

In general, human sound perception is such that a change in sound level of 3 dB is just noticeable, a change of 5 dB is clearly noticeable, and a change of 10 dB is perceived as a doubling or halving of the sound level (Cowan 1994).

Sources of information for this section are field measurements conducted by Project Consultants, regulatory information from the County of Madera, and sound level data provided by U.S. Electrical Motors.

3.13.1 Affected Environment

The Madera Ranch site is composed of agricultural and grazing land, with scattered residences. Sources of noise in the area include distant traffic, wildlife, agricultural activities, groundwater pumps, and irrigation district lift stations. A field investigation was conducted to quantify existing background noise conditions and noise from groundwater pumping operations on Madera Ranch. The investigation was conducted on November 6, 2000, between 7:30 a.m. and noon using a sound-level meter that was checked for proper calibration before and after each measurement session. Temperature, wind speed, and humidity were sampled manually throughout the day. There were minimal clouds and in the morning, wind conditions were generally calm (speeds less than 2 miles per hour [mph]). As the day progressed, wind speeds increased to the range of 8 to 13 mph.

Ambient sound levels of 35–51 dBA were measured throughout the day. The quietest ambient sound level (35 dBA) was measured in the early morning when wind speeds were lowest; this sound level was generated primarily by noise from distant traffic and natural sources (e.g., birds). As wind speeds increased, it became clear that the effects of the wind were governing the ambient sound level and increasing background sound levels.

Sound level measurements were taken in the vicinity of two groundwater pumps driven by diesel engines and in the vicinity of four groundwater pumps driven by electric motors. At a distance of 50 feet, the diesel engines produced sound levels of 81–86 dBA. At a distance of 25 feet, three of the electric pumps produced sound levels of 57–58 dBA, and the fourth electric pump produced a sound level of 68 dBA. The fourth pump was producing a high-frequency squeal, indicating that it may not have been operating properly. Diesel engines are probably louder than electric engines (Breault et al. 2009), which explains why they had a higher sound level at a further distance than the electric engines.

Sensitive receptors in the area of the proposed recharge and recovery wells include residences that are approximately 1,320 feet from the location of the nearest proposed new well. There are also sensitive residential receptors along the two canals where new lift stations would be located. The closest sensitive receptor to a noise source is a residence located approximately 300 feet from a proposed lift station on Main No.2 Canal.

3.13.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative there would be no adverse effects on noise. However, the future conditions could change to support agricultural activities. Potential effects would be evaluated by the County under CEQA depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect NOI-1: Exposure of Residences to Noise from Grading and Construction Activities

Construction of the canals and grading to develop the recharge basins under Alternative B would involve the use of heavy construction equipment. Table 3-26 summarizes typical noise levels produced by heavy equipment.

Table 3-26 Typical Noise Levels Produced by Heavy Equipment

Equipment	Typical Noise Level (dBA) 50 Feet from Source
Backhoe	80
Dozer	85
Grader	85
Scraper	89
Truck	88

Source: Federal Transit Administration 1995.

For this assessment, it is assumed that one backhoe and two graders could be operating in a local area concurrently and that they could operate at any time during the day or night. The combined sound from these sources is 89 dBA at 50 feet. The distances needed for a source of this sound level to attenuate to County noise-level standards are:

- 3,900 feet for 45 dBA (nighttime standard) and

- 2,600 feet for 50 dBA (daytime standard).

Residences near the southeastern end of Madera Ranch are located within 2,600 feet of the proposed recharge facilities. This effect is, therefore, considered adverse because noise levels would exceed County standards at these residences. Implementation of Environmental Commitment NOI-1to Employ Noise-Reducing Construction Practices would minimize the intensity and timing of the effect.

Effect NOI-2: Exposure of Residences to Noise from Well-Drilling Operations At each well site, well drilling would involve initial drilling 24 hours a day for several days, then intermittent drilling during daytime hours for several days. The specific types of drilling units to be used are not known. Experience from previous studies indicates that a source level of 85 dBA at 50 feet is a reasonably conservative assumption for well drilling operations. The distances needed for a source of this sound level to attenuate to County noise-level standards are:

- 2,900 feet for 45 dBA (nighttime standard) and
- 2,000 feet for 50 dBA (daytime standard).

Although all wells would be located at least 0.25 mile (1,320 feet) from the nearest residences, this analysis indicates that noise from drilling could exceed County noise standards at these residences. This effect therefore is considered adverse. Implementation of Environmental Commitment NOI-2to Employ Noise-Reducing Methods during Well-Drilling Operations would minimize the intensity and timing of the effect.

Effect NOI-3: Exposure of Residences to Noise from Operation of Engines at Wells A single pump with an engine rating of up to 100 hp would be used at each wellhead. The pumps could be either electric or propane-fueled. Data provided by U.S. Electrical Motors for a 100-hp electric motor running under no load (Roughton pers. comm.) indicate that the motor would produce a sound level of 56 dBA at 50 feet. To approximate the sound level produced under load, 3 dB were added to the no-load condition for a resulting source level of 59 dBA at 50 feet. The distances needed for a source of this level to attenuate to County noise-level standards are:

- 250 feet for 45 dBA (nighttime standard) and
- 140 feet for 50 dBA (daytime standard).

The sound level of a similarly sized pump operated by a propane-fueled reciprocating engine was calculated using the equations for reciprocating engines from Noise Control for Buildings, Manufacturing Plants, Equipment and Products (Hoover and Keith 1996). Based on these calculations, a 100-hp propane-fueled engine would produce a sound level of 75 dBA at 50 feet. This sound level represents a reasonable worst-case scenario at the well locations.

The distances needed for a source of this level to attenuate to County noise-level standards are:

- 1,250 feet for 45 dBA (nighttime standard) and
- 800 feet for 50 dBA (daytime standard).

All wells would be located at least 0.25 mile (1,320 feet) apart and would be located at least 0.25 mile (1,320 feet) from the nearest property line. Accordingly, no meaningful cumulative effects of simultaneous pump operation noise are anticipated. As such, the analysis is based on the noise from a single pump. This analysis indicates that noise from propane-fueled well pumps with the maximum horsepower rating is not likely to exceed County nighttime noise standards at the nearest residences. Therefore no adverse effect from operation of engines at wells is anticipated.

Effect NOI-4: Exposure of Residences to Noise from Operation of Engines at Lift Stations
Two propane-fueled pumps totaling 200 hp could be used at each of the lift stations located along the Main No. 2 Canal under Alternative B. Noise from engines typically increases at a rate of 3 dB for each doubling of horsepower (Hoover and Keith 1996). Using the sound data for the 100-hp pump described above, the noise level from the two pumps is estimated to be 78 dBA (75 dBA + 3 dB) at 50 feet. The distances needed for a source of this sound level to attenuate to County noise-level standards are:

- 1,600 feet for 45 dBA (nighttime standard) and
- 1,000 feet for 50 dBA (daytime standard).

The lift stations along Main No. 2 Canal potentially would be located as close as 300 feet to the nearest residence (Dorrance pers. comm.). This analysis indicates that there is potential for noise from the lift stations under the maximum horsepower scenario to exceed County noise standards at residences. This effect therefore is considered adverse. Implementation of Environmental Commitment NOI-4 to Employ Noise-Reducing Methods during Lift Station Operations would result in avoidance of the effect or minimization to below County standards.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used and a reduced number of ponds would be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. However, the expected footprint of facilities, including noise-producing pumps for recovery wells and lift stations, and associated construction, under Reduced Alternative B would be similar to Alternative B and would result in equivalent effects related to construction (grading and drilling) and operation (recovery and lift station pumps) noise near residences (Effects NOI-1, NOI-2, NOI-3, and NOI-4). Thus, noise effects are considered equivalent to those that would occur under Alternative B and are considered adverse. Implementation of Environmental Commitments NOI-1, NOI-2, NOI-3, and NOI-4 would reduce the intensity of these effects.

Alternative C—Water Banking Outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. However, the expected footprint of facilities, including noise-producing pumps for recovery wells and lift stations, and associated construction, under Alternative C would be similar to Alternative B and would result in equivalent effects related to construction (grading and drilling) and operation (recovery and lift station pumps) noise near residences (Effects NOI-1, NOI-2, NOI-3, and NOI-4). Thus, noise effects are considered equivalent to those that would occur under Alternative B and are considered adverse. Implementation of Environmental Commitments NOI-1, NOI-2, NOI-3, and NOI-4 would reduce the intensity of these effects.

Alternative D—Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B and lift stations would be built in locations different from those proposed under Alternative B. Thus, Alternative D would result in unique potential adverse effects related to lift stations (Effect NOI-5, described below). All other anticipated construction and operation effects under Alternative D would be similar to Alternative B and would result in similar effects related to construction (grading and drilling) and operation (recovery pumps) noise near residences (Effects NOI-1, NOI-2, and NOI-3). Thus, noise effects are considered equivalent to those that would occur under Alternative B for Effects NOI-1, NOI-2, and NOI-3and are considered adverse. Implementation of Environmental Commitments NOI-1, NOI-2, and NOI-3, respectively, would reduce the intensity of these effects.

Effect NOI-5: Exposure of Residences to Noise from Operation of Engines at Lift Stations

One propane-fueled pump totaling 200 hp could be used on the proposed lift station located on the GF Canal. Noise from engines typically increases at a rate of 3 dB for each doubling of horsepower (Hoover and Keith 1996). Using the sound data for the 100-hp pump described above, the noise level from the pump is estimated to be 78 dBA (75 dBA + 3 dB) at 50 feet. The distances needed for a source of this sound level to attenuate to County noise-level standards are:

- 1,600 feet for 45 dBA (nighttime standard) and
- 1,000 feet for 50 dBA (daytime standard).

As the final location of this station is not known, the lift station potentially could be located within 1,000 feet of a residence. This analysis indicates that there is potential for noise from the lift stations under the maximum horsepower scenario to exceed County noise standards at residences. This effect therefore is considered adverse. Implementation of Environmental Commitment NOI-4 (as discussed above under Effect NOI-4) would result in avoidance of the effect or minimization to below County standards.

Cumulative Effects

None of the effects described for each alternative above have the potential to result in an adverse cumulative contribution to local noise. No other construction is proposed during the anticipated construction period that would contribute to cumulative noise increases during construction. Operational noise from pumps could contribute to a cumulative local increase in noise effects. However, proposed mitigation (Environmental Commitments NOI-3 and NOI-4) is anticipated to reduce this effect at Madera Ranch during operations and thus not contribute to local cumulative effects. No additional mitigation is proposed.

As Alternative C is equivalent in scope and overall effect to Alternative B, it is anticipated that Alternative C would not contribute to cumulative noise effects. Alternative D could result in additional effects related to the propane-fueled pump, but this effect would be reduced by implementing Environmental Commitment NOI-4. As such, none of the alternatives is expected to contribute to cumulative effects.

3.14 Public Services and Utilities

This section describes the existing public services and utilities in the areas potentially affected by the Proposed Action and alternatives. The analysis addresses effects of each alternative on fire protection, police protection, wastewater (sewage), water service, and electricity.

Schools are not discussed because Madera Ranch is not located in the vicinity of a school and the alternatives would not cause any increase in schoolchildren or result in effects on school facilities. Solid waste is not discussed because construction and operation of the alternatives would not increase development that would require the disposal of solid waste.

3.14.1 Affected Environment

Information in this section is primarily from the Madera County General Plan Policy Document (1995b).

The Madera Ranch site is in the service areas of the following utility providers:

- The Pacific Gas and Electric Company (PG&E) (electricity);
- AT&T (telephone);
- County Fire Department, contracted to the California Department of Forestry (firefighting); and
- Madera County Sheriff's Department (law enforcement).

MID delivers water to Sections 1, 13 ½, and 14 of Madera Ranch, but Madera Ranch is not served by community drinking water, wastewater, or stormwater services, and there are no schools in the vicinity of Madera Ranch; therefore, these services and facilities are not discussed in this section.

Local

Local power and communication utility lines cross the Madera Ranch site. These lines serve development on the site, including the shop area and well facilities. An electrical substation is located immediately north of the site across Avenue 12. The County Fire Department and the California Department of Forestry provide fire protection to the site, and the County Sheriff's Department provides law enforcement services to the site. MID and GFWD provide irrigation water to farmers in the area, generally between March and October. Only part of Madera Ranch is located in MID or GFWD boundaries.

3.14.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative there would be no adverse effects on public services and utilities. However, future conditions would change to support agricultural activities. Potential effects would be evaluated by the County under CEQA, depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect PSU-1: Increased Demand for Utilities Alternative B would involve the installation of up to 49 new 75–100-hp groundwater wells and up to 20 lift station pumps, which would increase demand for electricity for the site. Electricity either would be provided by PG&E in accordance with PG&E and the California Public Utility Commission regulations or would be purchased directly from the power grid. A connection would be made to existing electric lines along either Avenue 7 or Avenue 9. To provide the necessary service, a new utility substation would be constructed on Madera Ranch. All costs associated with constructing and maintaining required facilities would be borne by MID. Because PG&E could provide service to the water banking facility along existing utility lines and MID would provide substation facilities, this action would not result in an adverse effect.

Effect PSU-2: Potential Disruption of Emergency-Response Routes As described in the Traffic and Circulation Section, all the local roadways are currently operating at acceptable Levels of Service. The construction-related activities would not substantially increase the number of daily and peak-hour vehicles currently traveling along these roadways and would not contribute to exceedance of traffic thresholds recommended by the Institute of Transportation Engineers. However, the increase in slow-moving traffic during construction in the vicinity of Madera Ranch could reduce emergency response times on the affected roads. Because of this potential increase in emergency response times, Effect PSU-2 is considered adverse. Implementation of Environmental Commitments PSU-1a and PSU 1b would minimize adverse effects associated with Alternative B.

Effect PSU-3: Temporary Disruption of Irrigation Service as a Result of Construction Several canals that currently provide irrigation water would be reconditioned or extended. These canals would need to be dry during construction and, therefore, would not be able to convey irrigation water during these times. To minimize the disruptions to irrigators using these canals, MID would ensure that construction on these facilities is limited to winter, when the canals are not required to deliver irrigation water. As such, Effect PSU-3 is not considered adverse.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used and a reduced number of ponds would be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. Thus, there would be no substantive differences in potential effects on public services and utilities between Alternative B and Reduced Alternative B. Reduced Alternative B would result in equivalent effects on electricity use, emergency services, and irrigation services (Effects PSU-1, PSU-2, and PSU-3). Adverse effects resulting from the potential disruption of emergency service routes during construction would be mitigated as described under Alternative B (Environmental Commitment PSU-1a and 1b).

Alternative C—Water Banking Outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, there would be no substantive differences in potential effects on public services and utilities between Alternatives A and B. Alternative C would result in equivalent effects on electricity use, emergency services, and irrigation services (Effects PSU-1, PSU-2, and PSU-3). Adverse effects resulting from the potential disruption of emergency service routes during construction would be mitigated as described under Alternative B (Environmental Commitment PSU-1a and 1b).

Alternative D—Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B and lift stations would be built in locations different from those proposed under Alternative B. However, there would be no substantive differences in potential effects on electricity use, emergency services, or irrigation services between Alternatives B and D. Alternative D would result in equivalent effects (Effects PSU-1, PSU-2, and PSU-3). Adverse effects resulting from the potential disruption of emergency service routes during construction would be mitigated as described under Alternative B (Environmental Commitment PSU-1a and 1b).

Cumulative Effects

Effects related to the disruption of emergency response routes could have cumulative impacts in Madera County. Development of a traffic safety plan (Measure PSU-2b) and notifying emergency service providers of traffic route changes (Measure PSU-2a) would negate any potential for cumulative effects. As Alternatives C and D are identical in scope and effect to Alternative B, it is not anticipated that Alternatives C and D would contribute to cumulative effects on public services.

3.15 Socioeconomics

This section presents the environmental background necessary to analyze the socioeconomic effects of the proposed alternatives. Specific topics include current employment, income, and demographic information for Madera County. Existing levels of agricultural production and income also are described.

Implementation of the alternatives could affect the socioeconomic characteristics of the study area by:

- temporarily increasing construction-related employment opportunities in the area, and

- increasing or decreasing the amounts of agriculture-related employment and income in Madera County.

This analysis assumes that enough construction workers to staff the activities reside within a reasonable commute distance from the site and that these workers already have housing; therefore, the effect of the alternatives on the local housing supply is expected to be minimal. Consequently, no setting or background information related to housing supply and housing availability is provided in the following section.

This socioeconomic analysis assesses the potential effects resulting from implementation of the alternatives, which would generate temporary employment related to construction and permanent employment related to operations. Effects on employment were evaluated for the Fresno metropolitan statistical area (MSA). Activities occurring at or near the site could trigger effects on employment and income if there is an insufficient local workforce. However, the site is within a reasonable commute distance from the cities that make up the Fresno MSA, which contains an adequate construction workforce.

The following assumptions were used to assess socioeconomic effects under each of the alternatives.

- Estimates of construction-related employment were provided by MID (Roughton pers. comm.). Implementation of the alternatives would generate about 101 temporary construction-related employment positions over the period of construction, and 1–2 permanent operations staff positions.
- Enough construction workers reside within a reasonable commute distance from the Madera Ranch site and presumably already have housing. Therefore, effects on population and housing are expected to be minimal and are not assessed further.
- Construction of the alternatives is not expected to take place within an existing residential area; therefore, implementation is not anticipated to result in the displacement of any existing residences or community facilities.

The socioeconomic effects associated with the alternatives would be focused on the effects on employment and income resulting from a small, temporary increase in regional employment during construction, and estimates about how farmers might respond to changes in water costs and reliability.

3.15.1 Affected Environment

The alternatives are proposed for Madera Ranch, which is located in southwestern Madera County. The Madera Ranch site and Madera County as a whole are characterized as highly rural areas with low population levels. However, the site is within a reasonable commute distance from the cities that comprise the Fresno MSA (e.g., Madera, the greater Fresno metropolitan area). This section includes background or regional employment and income information for the Fresno MSA, as defined by the California Employment Development Department. This MSA includes both Fresno and Madera Counties and occupies a geographic area described by the U.S. Bureau of Economic Analysis as possessing extensive economic interactions and linkages. Activities occurring at or near the site could trigger socioeconomic effects.

Methods and Terminology

Information for the socioeconomic analysis was obtained from the California Department of Finance, the U.S. Bureau of Economic Analysis, and the U.S. Census Bureau. In addition, Madera County's general plan documents (Madera County 1995a, 1995b), the County Economic Development Commission, and the California Water Plan Update (California Department of Water Resources 2005) were consulted for information related to current and future land use, population statistics, and planned growth rates for Madera County and the state. In addition, both the GFWD and MID have developed groundwater management plans to evaluate the availability of groundwater resources to support current and future demands. Information on existing agricultural uses and agricultural productivity was obtained from the County Agricultural Commissioner's Office.

Employment and Income

Overall, the labor market of the Fresno MSA is dominated by agriculture and agriculture-related services and industries. In addition to employment resulting from the direct production of a variety of both field and orchard crops, agriculture contributes indirectly to other MSA jobs in manufacturing (e.g., grain, nut, and fruit processing) and wholesale trade (e.g., farm and food processing machinery, and farm supplies).

The California Employment Development Department reports that 432,000 were in the labor force within the Fresno Metropolitan Service in March 2011. Of that amount, 353,100 were employed and 79,600 were unemployed for an unemployment rate of 18.4-percent.

Residents of the Fresno MSA generate a relatively large demand for retail products and services. Combined employment in the retail trade and professional services industries accounts for 49% (169,600) of the total number of jobs in the MSA (Table 3-27).

Table 3-27 Selected Employment Characteristics for the Fresno Metropolitan Statistical Area

Industry	Number of Full-Time and Part-Time Jobs
Total Labor Force	315,500
Farm (including production and services)	36,300
Non-farm	279,200
Mining and Construction	11,000
Manufacturing	25,000
Transportation, Public Utilities and Trade (including wholesale and retail)	54,200
Professional Services	26,400
Leisure and Hospitality	26,600
Government	68,600
Other	9,900

Source: California Employment Development Department 2011.

The traditional reliance of Madera County and the overall MSA on agricultural production and food processing as main sources of employment has resulted in substantial seasonal fluctuations in the unemployment rate. This, combined with a small industrial base, perpetuates consistently high unemployment rates.

Population and Demographics

The total population in Madera County in 2000 was 123,109; of this total, 68,775 residents (56%) lived in the unincorporated portions of the county (Table 3-28). For 2000, Madera County's ethnic composition ranged from 62% white to 1% Asian/Pacific Islander. The County is considered ethnically diverse; minority populations account for an estimated 38% of Madera County's total population.

Table 3-28 Population and Percent Ethnicity Data[*] for Madera County

Area	Total 2000 Population	White	African American	Native American	Asian/Pacific Islander	Hispanic
Madera County	148,632	87.6%	4.6%	3.3%	2.4%	51.7%
City of Madera	61,416	48%	2.7%	0.5%	0.1%	76.7%
City of Chowchilla	11,127	64%	10%	3%	1%	28%
Unincorporated Area	68,775	NA	NA	NA	NA	NA

Notes:
NA=Not applicable
*All ethnicity data population data (e.g., city and county) are from 2000 sources: California Department of Finance 2000a.

Median household income for Madera County is $36,286. Persons in poverty were estimated at 21% of the county population for the 2000 census year (Table 3-29).

Table 3-29 Income Data for Madera County

Area	Median Household Income	Percent above Poverty Level	Percent below Poverty Level
Madera County	$36,286	79	21

Source: U.S. Census Bureau 2001.

Relationship between Water Costs and Crop Production

About 86% of the cultivated lands in Madera County are permanent crops such as orchards or vineyards that are cultivated for many seasons without the need to replant each season. As such, these crops are established for long-term production and fallowing or abandonment from year to year is difficult. Permanent crop farmers tend to ensure these crops receive water in dry years so as not to compromise the ability of the crop to produce over the long term.

For those crops that are not permanent, farmers may choose to fallow land and wait until conditions are better for planting or change crop types to better balance the water costs and market values of the crop. However, permanent crops are difficult to change or fallow, and therefore, changes in water costs generally do not have an effect on permanent crop production or type.

Although the overall permanent crop production may not change in years when water costs are higher, the regional economy could be affected by farmers cutting other costs, such as employment and investment in equipment.

3.15.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative there would be no adverse effects on socioeconomics. However, the future conditions at Madera Ranch would change to support agricultural activities.

Potential effects would be evaluated by the County under CEQA, depending on the discretionary permits needed. Regardless of changes at Madera Ranch, the No Action Alternative would result in a decreased water supply reliability in the MID service area, which could adversely affect farming economies in the region by increasing water costs. With reduced supplies, farmers are likely to have to pay more for water and modify other operational costs, by measures such as reducing workforce. This would have an adverse effect on the regional economy.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect SE-1: Increase in Temporary Construction-Related Employment and Income in the Fresno Metropolitan Statistical Area Under Alternative B, approximately 100 seasonal workers would be employed annually for a period of 12 months. This work force would be required only for construction and not indefinitely. Generally, direct effects on employment would result from expenditures on the design, engineering, and construction of facilities. This spending also would result in direct effects on local businesses that provide goods and services to the engineering and construction firms. Construction positions most likely would be filled by residents of the local area, including residents of the greater Fresno MSA. Because implementing Alternative B would increase construction-related employment opportunities and income for local workers, Effect SE-1 is considered beneficial.

Effect SE-2: Increase in Permanent Employment and Income in the Local Area Attributable to Operation of the Water Supply Enhancement Project An estimated one to two jobs would be created by Alternative B to handle operation and maintenance responsibilities when the facilities are completed. The new jobs would generate minor direct effects on local businesses that provide goods and services needed to support operation of the water bank. The employment and income effects of Effect SE-2 are considered beneficial.

Effect SE-3: Effects on the Agricultural Economy Attributable to an Increase in Water Costs The costs associated with implementation of Alternative B would be paid by those who choose to use the bank by purchasing banking space. Water rates for non-participants would stay within the current range during all year types. In dry years, when farmers may want to recover banked water, additional water rates would apply to those who opt to participate in the bank by purchasing banking space to supplement their supplies. These water rates would be slightly less than projected costs of non-MID water, such as that obtained by transfers or spot market purchases of water.

Therefore, water costs would rise only in dry years and only related to the banked water. Because water costs are not expected to increase beyond the reasonable range of historical costs as a result of Alternative B, and because there would not be a change in crop production for the majority of crops as many of the crops in Madera County are permanent, there would be no adverse effect on agricultural economies related to increased water costs. Additionally, farmers could benefit in dry years by securing supplies at rates less than transfer costs or other options, such as spot market transfers.

Effect SE-4: Changes in Employment and Income in the Local Area because of Increased Water Supply Reliability Alternative B has the potential to have two differing effects on employment and income, one beneficial and one negative. The actual effect would depend on farmers' responses to changes in water costs and water reliability from year to year and the effect that has on their long-term planning for farming operations. The beneficial effect is related to improving the reliability of the surface water supplies for MID contractors, which would result in greater certainty in regard to maintaining the current agricultural lands. This certainty has the potential to result in increased employment and associated incomes because farmers are more likely to hire and retain workers and invest in equipment for long-term use. This increase in employment and income is beneficial.

However, in response to increased costs, some farmers may choose to reduce their workforce or not invest in equipment. These choices depend on crop type, existing workforce, and existing cultivated land. This could have a negative impact on the regional economy if these types of choices are made by many farmers over several years. As described above under SE-3, water costs are not expected to rise beyond the normal range of costs. The increased reliability has the potential to offset some of these costs. As such, it is not expected that there would be a substantial change, and this effect is not considered adverse.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used and a reduced number of ponds would be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. Thus, there would be no substantive differences in potential effects on public services and utilities between Alternative B and Reduced Alternative B. Increased water costs are not expected to have an effect on the environment (SE-3). Reduced Alternative B would result in equivalent effects (Effects SE-1 and SE-2) on temporary and permanent employment. Similar to Alternative B, Reduced Alternative B has the potential to result in beneficial socioeconomic effects (SE-4).

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative C, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, there would be no substantive differences in potential effects on public services and utilities between Alternatives B and C. Increased water costs are not expected to have an effect on the environment (SE-3). Alternative C would result in equivalent effects (Effects SE-1 and SE-2) on temporary and permanent employment. Alternative C would result in beneficial socioeconomic effects (SE-4).

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that recharge is achieved using engineered recharge basins in lieu of the natural swales that occur on the site and some differences in the types of conveyance facility improvements. Thus, there would be no substantive differences in potential effects on public services and utilities between Alternatives B and D. Alternative D would result in equivalent effects (Effects SE-1 and SE-2) on temporary and permanent employment. Increased water costs are not expected to have an effect on the environment (SE-3). Alternative D would result in beneficial socioeconomic effects (SE-4).

Cumulative Effects

As none of the alternatives would result in adverse effects on socioeconomics, there would be no cumulative effects.

3.16 Traffic and Circulation

This section describes the existing traffic and circulation conditions in the areas potentially affected by the proposed alternatives. It discusses the affected environment, relevant regulations and policies, methods of analysis, and possible effects.

3.16.1 Affected Environment

Roadway Levels of Service Level of service (LOS) measures the quality of service provided by a roadway. LOS criteria established by the Transportation Research Board are shown in Table 3-30. These criteria use a letter rating to describe the peak-period driving conditions for a particular facility. The roadway traffic conditions become progressively worse from A to F.

Table 3-30 Roadway Level of Service Definitions

Level of Service Rating	Definition
A	Free flow; insignificant delays
B	Stable operations; minimal delays
C	Stable operations; acceptable delays
D	Approaching unstable; queues develop rapidly but no excessive delays
E	Unstable flow; significant delays
F	Forced flow; low operating speeds

Source: Transportation Research Board 1994.

LOS criteria for highways are established by Caltrans and take into account numerous variables, including annual average daily traffic, roadway capacity, grade, and environment (urban versus rural). According to Caltrans policy and the County's criteria, LOS D is acceptable for planning purposes, and LOS E and F are unacceptable. As shown in Table 3-31, all the roadways potentially affected by the alternatives are currently operating at LOS D or better; therefore, all the roadways are operating at acceptable levels.

Table 3-31 Roadway Characteristics near Madera Ranch

Roadway	Responsibility	Functional Classification	Average (vehicles per day)	Peak Hour (vehicles per day)	LOS
SR 99[a]	Caltrans	4-lane freeway	62,000–63,000	5,600–6,200	D
Avenue 7[b]	Madera County	2-lane local road	3,256	326	C
Avenue 10[c]	Madera County	2-lane local road	2,440	244	B/C
Avenue 12 [b]	Madera County	2-lane local road	2,419	242	A/B
Road 16[b]	Madera County	2-lane local road	371	37	A
Road 21[b]	Madera County	2-lane local road	Unavailable	Unavailable	A

Roadway	Responsibility	Functional Classification	Average (vehicles per day)	Peak Hour (vehicles per day)	LOS

Notes:
[a] Source: California Department of Transportation 2007.
[b] Source: Madera County Transportation Commission 2007. Traffic counts for Avenue 7 are from 2004, Avenue 12 from 2007, and Road 16 from 2005. Counts have never been conducted for Road 21.
[c] Source: Stone pers. comm. and Levine pers. comm. Based on the most recent available data from 1998.

Madera County is in a major transportation corridor between northern and southern California; SR 99 is the primary route for north/south travel. The county's economy is based on farming, agricultural processing, and manufacturing. Because most of the county's products are shipped to outside locations, interstate and intrastate transportation are vital.

Roadways As shown in Figure 3-8, Madera Ranch is regionally served by SR 99, which is generally a four-lane divided roadway (oriented north/south), and locally served by Avenues 7, 10, and 12 and Roads 16 and 21, which are all two-lane roadways maintained by the County. SR 99 is under the jurisdiction of Caltrans. Roadways and roadway segments potentially affected by the WSEP are:

- SR 99 from Madera to Fresno,
- Avenue 7 from Firebaugh to SR 99,
- Avenue 14 to Avenue 23 to Avenue 10,
- Avenue 10 from Road 23 to Road 21 (the Madera Ranch site),
- Avenue 12 from Road 16 to SR 99,
- Road 16 from Chowchilla to Avenue 12, and
- Road 21 from Avenue 12 to Avenue 7.

Information about the most current traffic volumes, roadway classifications, and LOS is provided in Table 3-31. Avenues 7 and 12 are considered major truck routes (Stone pers. comm.). Although estimates of truck traffic on local roadways serving the Madera Ranch site are currently unavailable, it is estimated that the percentage of trucks or other slower moving vehicles (e.g., farm vehicles) is higher than average because of local agriculture.

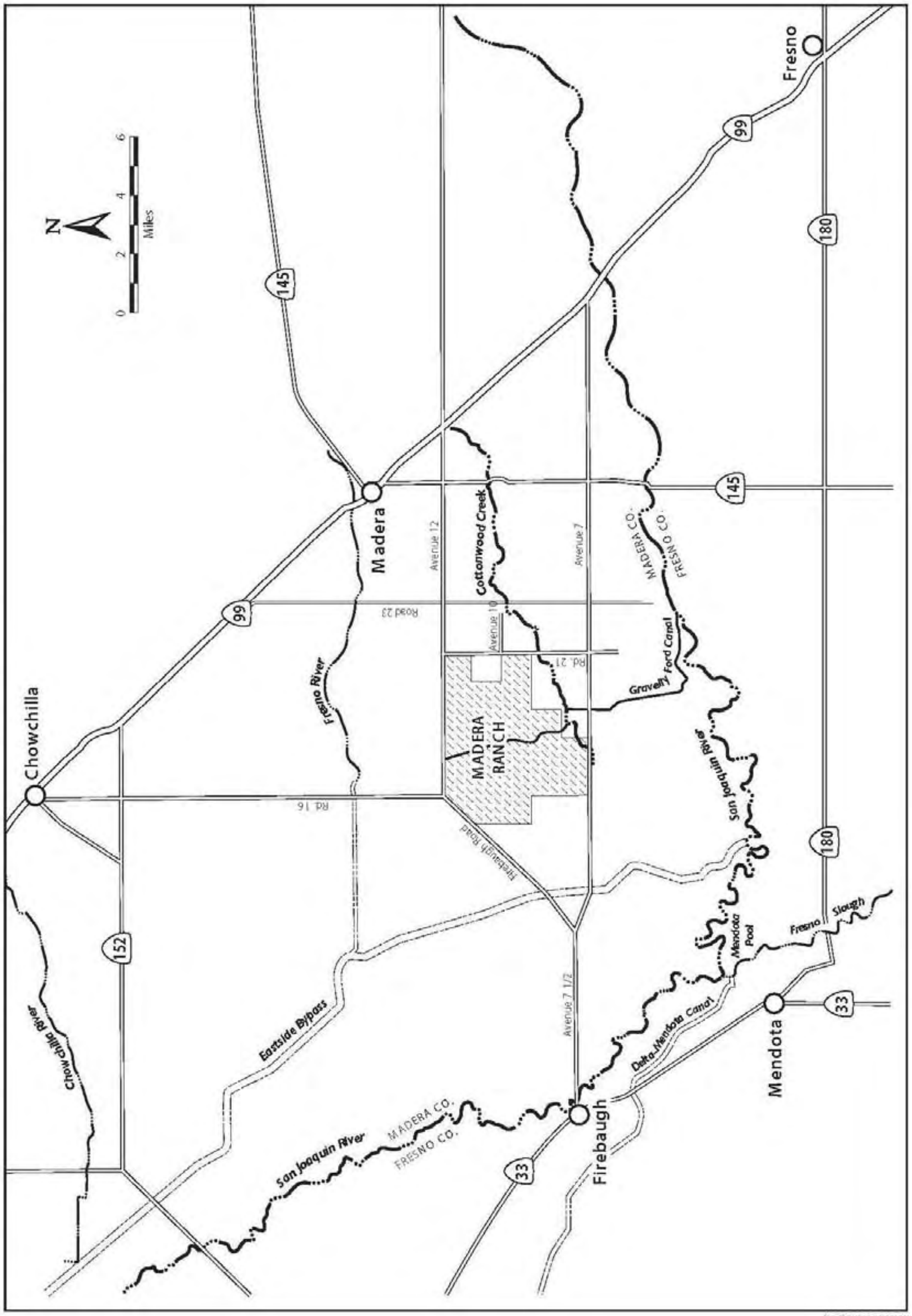


Figure 3-8 Regional and Local Roadway Network near Madera Ranch

3.16.2 Environmental Consequences

Traffic counts from 1998 through 2007 are used to provide traffic data for roadways in the vicinity of Madera Ranch. Consequently, 1998–2007 traffic data are used to characterize the baseline traffic condition for this transportation and circulation analysis. Traffic and circulation effects would be limited to construction, and each of the alternatives involves a similar construction effort. As such, it is assumed that each of them generates the same vehicle trips.

Vehicle Access and Parking

Madera Ranch is located in the largely agricultural western portion of Madera County, approximately five miles southwest of the city of Madera and 10 miles northwest of Fresno. The Madera Ranch site would be accessed locally from Avenues 7 and 12. Avenue 10 would provide direct access to the site.

Trip Distribution

As shown in Table 3-34, the traffic analysis assumes that construction workers under the alternatives would come from the Fresno MSA. The analysis assumes origination of the construction workforce would be:

- 70% from Fresno,
- 20% from Madera,
- 5% from Chowchilla, and
- 5% from Firebaugh.

The analysis assumes that 100% of the total number of heavy-truck trips would be generated from the greater Fresno metropolitan area.

Trip Generation

To assess the magnitude and directional variation of vehicle trips associated with construction of the alternatives, vehicle-trip generation was analyzed using an estimate of the required construction-related workforce. Assuming a worst-case scenario, construction of the alternatives could require up to 60 construction workers. Implementation of the Proposed Action could generate up to 3,600 heavy-truck (e.g., concrete, equipment) trips during construction of the recharge basins. Table 3-32 provides an estimate of the total number of construction-related vehicle trips that would be generated, including the peak and average daily vehicle trips.

The traffic and circulation analysis also assumes a worst-case scenario in which each of the 60 workers would drive a separate vehicle to Madera Ranch, making two trips per day, or one round-trip from home to the site and back. Under this scenario, construction of the alternatives would result in an average of approximately 176 vehicle trips per day and about 68 total vehicle trips per day during the peak morning and afternoon traffic periods (Table 3-32) during the period of construction (approximately 365 days).

In addition, it is estimated that construction-related activities would include the use of several types of equipment, including backhoes, scrapers, water trucks, pickup trucks, and front loaders. It is assumed that equipment would be stored on site while in use and would not result in a substantial increase in the overall daily trip generation.

O&M–related activities would require only occasional inspection visits; therefore, operations and maintenance–related traffic would be negligible and is not expected to affect the operating conditions of existing roadways. Consequently, operations-related traffic is not addressed further in this analysis.

Table 3-32 Anticipated Construction Vehicle Trip Generation and Workforce Distribution

Vehicle Origin City	Percent Distribution of Local Workforce	Daily Workforce	Daily Vehicle Trips	Daily Peak-Hour Vehicle Trips
Fresno				
Construction Workers	70.	42	84	42
Heavy Trucks	100.	28	56	8
Total		70	140	50
Madera	20	12	24	12
Chowchilla	5	3	6	3
Firebaugh	5	3	6	3
Total	**100**	**88**	**176**	**68**

Alternative A—No Action

Under the No Action Alternative there would be no adverse effects on traffic. However, the future conditions would change to support agricultural activities. Some increase in traffic in the region could occur as a result of development. Potential effects would be evaluated by the County under CEQA, depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect TRAF-1: Temporary Construction-Related Increase in Traffic Volumes on Local and Regional Roadways Construction of Alternative B temporarily would increase the traffic volumes on SR 99; Avenues 7, 10, and 12; and Roads 16 and 21. It is assumed that the route preferred by construction workers and truck drivers traveling from the Fresno metropolitan area would be north along SR 99 to Avenue 7, west to Road 21, north to Avenue 10, and west to the Madera Ranch site. Workers originating from Madera most likely would travel south along SR 99 to Avenue 12, west to Road 21, south to Avenue 10, and west to the site.

From Chowchilla, workers most likely would travel south along Road 16 to Avenue 12, east to Road 21, south to Avenue 10, and west to the Madera Ranch site. Workers originating from Firebaugh most likely would travel east along Avenue 7 to Road 21, north to Avenue 10, and west to the site.

Using the above-mentioned travel pattern assumptions, Figure 3-9 identifies the preferred travel routes for both daily and peak-hour traffic volumes. Table 3-33 also provides estimates of the increase in traffic on local and regional roadways that would be anticipated to result from the construction workforce commuting to and from the construction site. As the anticipated construction activities are similar in scope, the anticipated construction workforce is assumed to be identical, regardless of alternative.

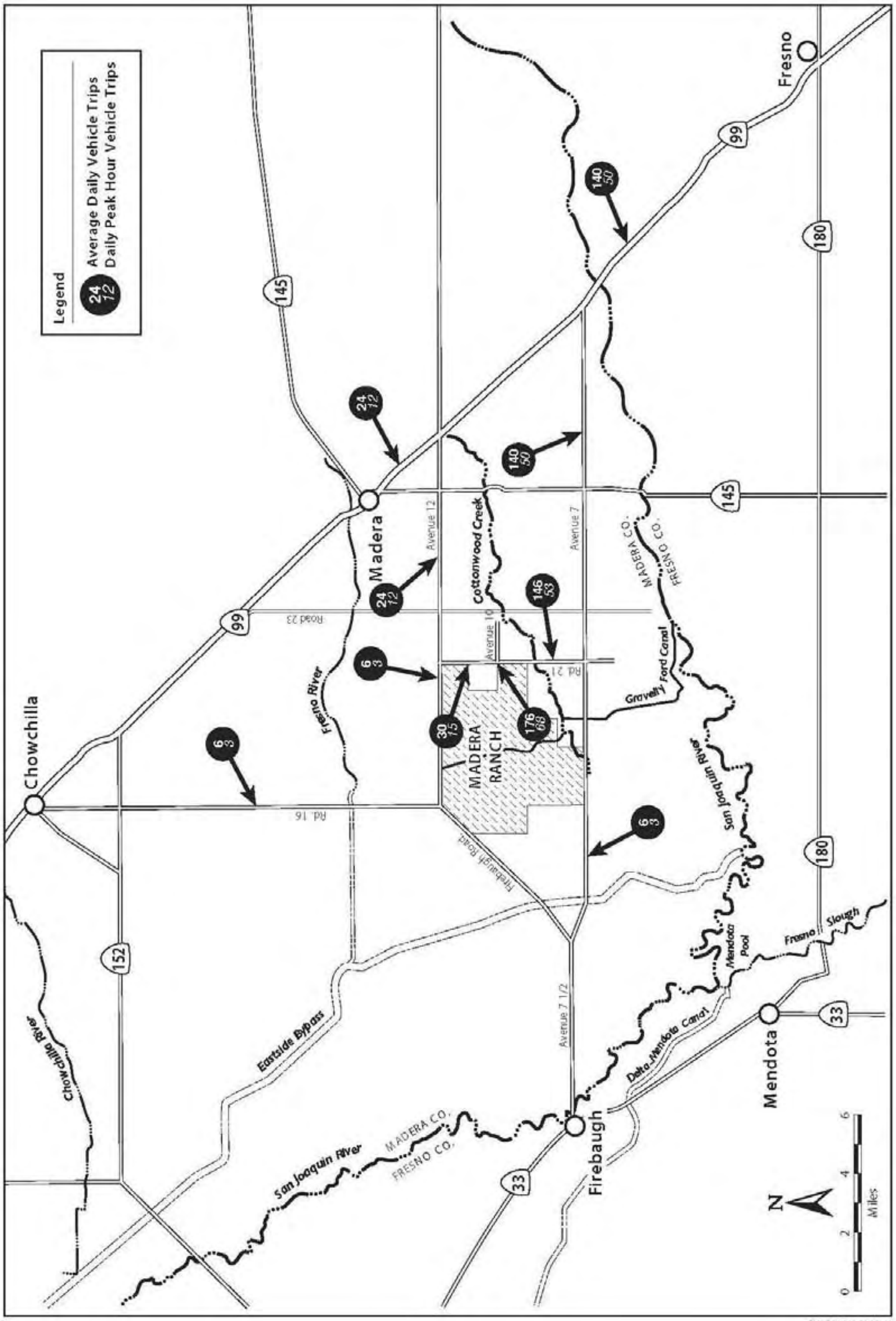


Figure 3-9 Project-related Trip Distribution – Construction Period

As described above, all the roadways are currently operating at an acceptable LOS. Because construction-related activities would not substantially increase the number of daily and peak-hour vehicles traveling along these roadways and would not contribute to exceedance of traffic thresholds recommended by the Institute of Transportation Engineers, Effect TRAF-1 is not considered adverse.

Table 3-33 Increase in Construction-Related Traffic on Regional and Local Roadways

Roadway Segment	Existing Average Daily Trips	Existing LOS	Daily Trips (Percent Increase)	Existing Peak-Hour Trips	Peak-Hour Trips (Percent Increase)
State Route 99	52,000	D	164 (0.3)	4,700	62 (1)
Avenue 7	3,300	B/C	146 (4)	330	53 (16)
Avenue 10	2,440	B/C	176 (7)	244	68 (28)
Avenue 12	2,270–8,520	B/C	30 (0.4–1)	227-852	15 (2–7)
Road 16	580	B/C	6 (1)	58	3 (5)
Road 21	NA	B/C	176 (NA)	NA	68 (NA)

NA = not available.
LOS = level of service.

Effect TRAF-2: Potential Increase in Construction-Related Traffic Volume Delay and Hazard on Local and Regional Roadways Construction-related activities would involve the daily use of heavy trucks, which could increase safety hazards on local roadways. Although construction-related activities would take place for only a short time, these activities would result in greater-than-normal truck traffic along local roadways. As additional heavy trucks travel to and from the Madera Ranch site, there could be conflicts between drivers of slow-moving vehicles (including farm equipment) and drivers of other vehicles on local roadways; therefore, Effect TRAF-2 is considered adverse. Implementation of Environmental Commitment PSU-1b, Implement a Traffic Safety Plan, would minimize the intensity of this effect.

Effect TRAF-3: Potential Damage to the Roadway Surface during Construction The increased volume and frequency of vehicle traffic along local and regional roadways during the construction period would not result in a substantial deterioration of the roadway surface. However, heavy trucks and construction equipment accessing the site could affect the structure or maintenance needs of specific turnout or access points from local roadways. Currently, both the County and Caltrans implement programs that provide for the maintenance of safe and reliable roadways. Effect TRAF-3 is considered adverse. Implementation of Environmental Commitment TRAF-1, Implement a Road Improvement Plan, would minimize the timing and intensity of this effect.

Effect TRAF-4: Potential Increase in the Demand for Parking Space at the Construction Site(s) Implementation of Alternative B would increase the demand for parking spaces for construction employees and would require the development of an equipment staging area at the Madera Ranch site. However, as described more fully in the Alternatives Section, adequate parking and equipment staging areas would be included as part of Alternative B. Because construction-related parking and equipment storage needs would be addressed in the design of the alternative, Effect TRAF-4 is not considered adverse.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used and a reduced number of ponds would be constructed. Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. This would not result in changes to the overall construction and/or operational traffic patterns or levels anticipated under Alternative B and would result in equivalent effects (Effects TRAF-1, TRAF-2, TRAF-3, and TRAF-4). Thus, traffic effects are considered similar to those that would occur under Alternative B and are considered adverse. Implementation of Environmental Commitments PSU-1b and TRAF-1 would reduce the intensity of these effects.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, engineered basins would be built earlier in the design cycle than under Alternative B. This would not result in changes to the overall construction and/or operational traffic patterns or levels anticipated under Alternative B and would result in equivalent effects (Effects TRAF-1, TRAF-2, TRAF-3, and TRAF-4). Thus, traffic effects are considered similar to those that would occur under Alternative B and are considered adverse. Implementation of Environmental Commitments PSU-1b and TRAF-1 would reduce the intensity of these effects.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is nearly identical in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B and lift stations would be built in locations different from those proposed under Alternative B. This would not result in changes to the overall construction and/or operational traffic patterns or levels anticipated under Alternative B and would result in equivalent effects (Effects TRAF-1, TRAF-2, TRAF-3, and TRAF-4). Thus, traffic effects are considered similar to those that would occur under Alternative B and are considered adverse. Implementation of Environmental Commitments PSU-1b and TRAF-1 would reduce the intensity of these effects.

Cumulative Effects

Temporary construction (Effect TRAF-1, TRAF-2 and TRAF-3) and parking effects (Effect TRAF-4) would not contribute to any cumulative effect as construction traffic is only temporary in duration and the project would provide sufficient parking for the activity under all of the alternatives.

As both Alternatives C and D are equivalent in scope and overall effect to Alternative B, it is anticipated that neither Alternative C nor D would contribute to cumulative traffic effects.

3.17 Water Resources

This section examines the potential effects of the proposed alternatives on water quality, as influenced by surface water hydrology and flooding, groundwater hydrology, surface water quality, and groundwater quality.

3.17.1 Affected Environment

This section provides an overview of water quality conditions in surface water and groundwater resources of the affected environment. The affected environment consists of water resources that exist within or flow through the study area, an area that includes Madera Ranch; the immediate surrounding area; the underlying groundwater aquifer; and surface drainage features such as GF Canal, Cottonwood Creek, the Fresno River, and the San Joaquin River. This section also discusses potential environmental effects on water quality associated with the alternatives and their conformance with the applicable federal, state, and local regulations.

MID and previous property owners collected a large amount of data for evaluating the existing physical and chemical conditions in surface water and groundwater resources in the area. These data include hydrologic and geophysical properties of soils, deeper geologic features, and groundwater aquifers. All of these data were evaluated for this analysis.

Climate

The San Joaquin Valley is surrounded by the Coast Ranges to the west, by the San Emigdio and Tehachapi Mountains to the south, by the Sierra Nevada to the east, and by the Delta and Sacramento Valley to the north. The climate of the valley floor is arid to semi-arid with dry, hot summers and mild winters. Summer temperatures may be higher than 100 degrees Fahrenheit (°F) for extended periods; winter temperatures are only occasionally below freezing (32°F). The average annual rainfall at Madera Ranch is approximately 11 inches, most of which falls between October and March. The winter snowpack, which accumulates above 5,000 feet elevation, primarily in the Sierra Nevada, supplies the vast majority of water in the basin. The west-side streams contribute little to water totals in the valley because the Coast Ranges are too low to accumulate a snowpack, and their eastern slopes are subject to a rain shadow phenomenon, producing only seasonal runoff.

Surface Water

The San Joaquin River is the major surface water feature south and west of the area (Figure 2-1). The total San Joaquin River basin drains 7,395 square miles, of which 4,320 square miles are in the Sierra Nevada and 2,273 square miles are in the San Joaquin Valley (Kratzer et al. 2002). According to USGS flow records from 1951 to 1995, 66% of the average San Joaquin River flow comes from three major east-side river basins: the Merced River (15%), the Tuolumne River (30%), and the Stanislaus River (21%) (Kratzer et al. 2002). The remaining flow in the San Joaquin River comes from the Bear Creek Basin, which includes Mud and Salt Sloughs, and small ephemeral creeks that drain from the west, including Orestimba Creek, Del Puerto Creek, and various drainage canals.

The other two major rivers in the action area are the Fresno River and the Chowchilla River. The Fresno River drains a watershed of approximately 237 square miles above Hidden Dam and

Hensley Lake. Historically, the Fresno River has had ephemeral flows consisting of large winter uncontrolled flows and no summer flows. The Chowchilla River forms the northern boundary of the Madera area and drains approximately 236 square miles above Buchanan Dam. The Chowchilla River, like the Fresno River, has ephemeral flows consisting of large winter uncontrolled flows and no summer flows. Minor drainages in the vicinity of Madera Ranch include Cottonwood Creek and its tributaries (Figures 2-1 and 2-2). These minor drainages convey water from the Madera Canal to local canals, and all of their flows are diverted for use. Madera Canal is 36 miles long and extends northwest from Friant Dam to Ash Slough and diverts water to MID. The canal crosses the Fresno River 3 miles downstream of Hidden Dam. West of the area is the Eastside Bypass, which conveys uncontrolled flows from the San Joaquin River and from miscellaneous drainages to northwestern Madera County.

Cottonwood Creek is an ephemeral stream in which MID and GFWD maintain flow recorders. The creek is fed by runoff within a rural basin that lies generally between the Sierra foothills and SR 99 and SR 49. Data from 1954 through 2003 indicate that natural flows occur only during the rainy season, typically beginning in mid-January and ending in late March, with the highest flows in February. In wet years, the creek frequently overflows its banks at the intersection of Road 23 and Avenue 10 (two miles east of the ranch) and on the south side of the ranch. Federal Emergency Management Agency (FEMA)-designated floodplains at Madera Ranch include the southeast half of Sections 13, 22, and 28. All of these floodplains are associated with Cottonwood Creek, which crosses Madera Ranch in Section 28 only. During the irrigation season (typically beginning in late March and running through September) MID uses the creek as an extension of the Main No. 2 Canal. Creek flows during this time are Millerton Lake and Hidden Lake waters being delivered to farmers by MID. Without these deliveries, the creek would be dry during this time throughout Madera Ranch and its vicinity.

Surface Water Quality Surface waters from the San Joaquin River, Fresno River, and Cottonwood Creek have been used to irrigate land around and on Madera Ranch for more than 100 years. In general, these waters are known for their high quality for agricultural use.

The average specific conductance for the San Joaquin River is 45 microSiemens per centimeter (µS/cm) which refers to the electrical conductivity of water (approximately 28 mg/L TDS; Table 3-34), which indicates a much lower TDS than the groundwater beneath Madera Ranch, which averages 466 µS/cm (approximately 291 mg/L TDS). Friant and Hensley Lake water delivered to Madera ranch in 2005–2007 had a TDS ranging from 28 to 100 mg/L, whereas groundwater quality beneath the ranch during this same period ranged from 180 to 660 mg/L TDS (MID groundwater monitoring report summary October 29, 2007). The 2001 Annual Water Quality Report for Hensley Lake (Chan 2002) states that nutrient alkalinity and chemical oxygen demand data show that excessive nutrients are not present. The average specific conductance for the Fresno River below Hensley Lake is 116 µS/cm (approximately 72.5 mg/L TDS; Table 3-35), also lower than the groundwater at Madera Ranch. Tables 3-34 and 3-35 present water quality data for the San Joaquin River and Fresno River, respectively, and are representative of the source water for the Proposed Action. The source water for the WSEP would dilute concentrations of minerals and other constituents in the native groundwater, and, as a consequence, recovered water would be of generally better quality than the native groundwater.

Table 3-34 Summary of Water Quality Data: San Joaquin River below Friant Dam, 1958–1988

	Count[a]	Maximum	Minimum	Average[b]	Criteria
Flow (cfs)	91	7,090	25	411	Not listed
pH (standard units)	123	8.2	6.5	7.1	<6.5 or >8.5[c]
Water temperature (ºF)	93	68	39	51	Not listed
Specific conductance (µS/cm at 25ºC)	122	120	25	45	150[c]
Dissolved oxygen (mg/L)	121	15.5	6.4	11.7	Not listed
Calcium (mg/L as Ca)	52	15	2	3.5	Not listed
Magnesium (mg/L as Mg)	49	6.2	0.1	1	Not listed
Sodium (mg/L as Na)	117	11	1.6	3.8	20[d]
Potassium (mg/L as K)	35	2.9	0.4	1	Not listed
Chloride (mg/L)	103	8.5	0.8	3.3	250[g]
Sulfate (mg/L as SO_4)	29	8.2	0.3	3.2	250[g]
Fluoride (mg/L as F)	9	0.3	0.1	0.3	2.0[e]
Silica (mg/L as SiO_2)	15	14	9	12.5	Not listed
Boron (mg/L as B)	31	0.2	0.07	0.081	2.0[f]
Ammonia nitrogen (mg/L as N)	1	0.04	0.04	0.04	Temperature-dependent
Nitrate nitrogen (mg/L)	14	4.1	0.08	0.64	10[c,g]
Nitrogen, ammonia and organic, total (mg/L as N)	25	3.2	0.03	0.39	Not listed
Nitrate + nitrite (mg/L as N)	15	0.16	0.02	0.04	10[c,g]
Phosphorus dissolved (mg/L)	19	0.25	0.02	0.04	Not listed

Source: Data taken from Bookman-Edmonston 2003.

[a] Number of samples with detectable constituents.

[b] Flow-weighted average of all detectable constituents.

[c] RWQCB, Basin Plan Amendment Criteria (1998).

[d] Sodium criteria for people on a 500- mg/L sodium diet. U.S. EPA National Drinking Water Standard (2004).

[e] Fluoride criteria are still under review by the DHS (2004).

[f] Data in µg/L converted to mg/L (µg/L x 1000). RWQCB, Basin Plan Amendment Criteria (1998)—2.0 (15 March–15 September) and 2.6 (16 September–14 March).

[g] U.S. EPA National Drinking Water Standard (2004).

Table 3-35 Summary of Water Quality Data: Fresno River below Hidden Dam, 1958–1988

	Count[a]	Maximum	Minimum	Average[b]	Criteria
Flow (cfs)	59	1,100	0	83	Not listed
pH (standard units)	82	9.2	6.6	7.3	<6.5 or >8.5$_c$
Water temperature (ºF)	72	95	32	59	Not listed
Specific conductance (µS/cm at 25ºC)	83	548	57	116	150[d]
Dissolved oxygen (mg/L)	82	14	3.1	9.9	Not listed
Calcium (mg/L as Ca)	40	48	4.3	9.2	Not listed
Magnesium (mg/L as Mg)	40	19	0.6	1.9	Not listed
Sodium (mg/L as Na)	81	61	5	9.7	20[e]
Potassium (mg/L as K)	33	23	0.9	1.4	Not listed
Chloride (mg/L)	80	120	3.2	9	250[f]
Sulfate (mg/L as SO_4)	31	43	0.2	2.6	250[f]
Fluoride (mg/L as F)	11	0.2	0.1	0.1	2g
Silica (mg/L as SiO_2)	20	35	14	22.9	Not listed
Boron (mg/L as B)	29	1.2	0.01	0.113	2.0[h]
Nitrate nitrogen (mg/L)	27	4	0.02	1.06	10[c,d]
Nitrogen, ammonia and organic, total (mg/L as N)	2	0.6	0.4	0.6	Temperature-and pH-dependent
Phosphorus dissolved (mg/L)	3	0.16	0.04	–	Not listed

	Count[a]	Maximum	Minimum	Average[b]	Criteria

Source: Data taken from Bookman-Edmonston 2003.
– = No data.
[a] Number of samples with detectable constituents.
[b] Flow-weighted average of all detectable constituents.
[c] RWQCB, Basin Plan Amendment Criteria (1998).
[d] Criteria for San Joaquin River. No criteria listed for the Fresno River in the RWQCB, Basin Plan Amendment Criteria (1998).
[e] Sodium criteria for people on a 500- mg/L sodium diet. U.S. EPA National Drinking Water Standard (2004).
[f] U.S. EPA National Drinking Water Standard (2004).
[g] Fluoride criteria are still under review by the DHS (2004).
[h] Data in µg/L converted to mg/L (µg/L x 1000). RWQCB, Basin Plan Amendment Criteria (1998)—2.0 (15 March–15 September) and 2.6 (16 September–14 March).

Section 303(d) of the CWA establishes the total maximum daily load (TMDL) process to assist in guiding the application of state water quality standards. Under this section, states must identify streams whose water quality is impaired (affected by the presence of pollutants or contaminants) and establish the TMDL or the maximum quantity of a particular constituent that a water body can assimilate without experiencing adverse effect (U.S. Environmental Protection Agency 2007). The Fresno River, Cottonwood Creek, and upper San Joaquin River are not included on the 303(d) list. The 303(d) list does include reaches of the San Joaquin River, but all of the listed river reaches are downstream of the Madera Canal diversion and are not pertinent to this action.

EPA's STORET database (Storage and Retrieval of U.S. Waterways and Parametric Data) was searched for surface water quality information for Cottonwood Creek, but no data were available (STORET 2007). Because of the operations summarized above, the quality of Cottonwood Creek water is likely similar to that of all other MID conveyances during the irrigation season. During the rainy season (and based on the surrounding rural land uses), water quality is suspected to be similar to typical small rural streams, which are primarily dependent on mineral composition of the soils and associated parent materials within a watershed, hydrologic characteristics, and sources of contaminants in the watershed.

Groundwater

Madera Ranch is located in the Madera subbasin of the San Joaquin Valley Groundwater Basin. The total surface area of the subbasin is 394,000 acres or 614 square miles (California Department of Water Resources 2004). The Madera subbasin aquifer system consists of unconsolidated continental deposits, including older Tertiary and Quaternary age deposits overlain by a younger Quaternary deposit (California Department of Water Resources 2004). Groundwater recharge in the Madera subbasin occurs from river and stream seepage, deep percolation of irrigation water, canal seepage, and intentional recharge (California Department of Water Resources 2004). Groundwater flow is generally southwestward in the eastern portion of the subbasin, and to the northwest in the western portion (California Department of Water Resources 2004). However, groundwater flow directions vary on a local basis as a result of intense agricultural, municipal, and industrial groundwater pumping that also has caused overdraft in a variety of locations, including Madera Ranch. See the section on Water Supply, for additional information about groundwater hydrology.

Groundwater Quality Groundwater in the vicinity of Madera Ranch is used primarily for agricultural supply, although domestic wells serve rural residents. The section on Geology, describes the geologic and hydrogeologic characteristics of the local groundwater aquifer system, which is composed of an unconfined layer above the Corcoran Clay layer (E-clay) and a confined layer located beneath the Corcoran Clay layer.

Groundwater quality differences between the confined and unconfined aquifers are difficult to distinguish from production well samples because the majority of wells are perforated both above and below the Corcoran Clay, providing a mix of waters from both aquifers. In addition, the clay is thin to absent in some areas. Consequently, the majority of well sample data represent an average of water quality from within the confined and unconfined aquifers. However, it is known that the base of fresh water in the confined aquifer beneath the E-clay layer occurs about 1,000 feet below ground surface. The underlying saline groundwater originated from prehistoric periods when the Central Valley was a marine environment inundated by salt water (California Department of Water Resources 1975).

In general, groundwater quality in the eastern San Joaquin Valley is excellent with the dominant cation and anion being sodium and bicarbonate, respectively. The confined aquifer tends to have larger proportions of calcium. At the western edge of Madera County near the San Joaquin River, sodium and chloride are more prevalent. Nitrate is the most prevalent constituent that exceeds drinking water maximum contaminant levels (MCL) in the eastern San Joaquin groundwater basin (U.S. Geological Survey 2001). Agricultural practices are known to be the major cause of this nitrate contamination, with the MCL of 10 PPM of nitrogen being exceeded in about 40% of shallow wells. Concentrations of trace metals and other toxic inorganic constituents such as selenium, arsenic, and boron are generally low. The USGS frequently has detected pesticides in groundwater samples from the eastern San Joaquin Valley. However, only five pesticides were found in more than 10% of the samples, including atrazine, desethylatrazine, simazine, 1,2-dibromo-3-chloropropane (DBCP), and diuron (U.S. Geological Survey 2001). Concentrations of pesticides were generally low (less than 0.1 parts per billion [PPB]) and less than drinking water MCL. The widely used soil fumigant DBCP violated its MCL (0.2 PPB) in about 20% of domestic wells and 40% of agricultural wells located in vineyard production areas. Because this regional data showed elevated nitrate and DBCP, sampling of groundwater was conducted at Madera Ranch to determine whether this was an issue of concern.

Groundwater samples were collected from wells on the Madera Ranch site during 1999–2001 (TRC 1999, 2002) and 2005–2007 and were tested for organic and inorganic constituents. The locations of these wells are shown on Figure 3-10. Seven wells were tested for organic constituents. No organic constituents were detected, except for 1,2,3-Trichloropropane, which was detected in two wells located in Section 1 (RW-2 and RW-4) but was not detected in a third well located in Section 1 (RW-1) or in a downgradient well located in Section 4 (RW-21) (Table 3-36). There are no state and federal drinking water standards for this fumigant, but EPA Region IX has listed a health advisory – a drinking water equivalent level of approximately 0.02 micrograms per liter (µg/L). Contacts with the Madera County Agricultural Commission indicate that agricultural chemicals have been used on site, but based on a review of material safety data sheets, 1,2,3-Trichloropropane was not identified as an ingredient in the agricultural chemicals applied on site historically (TRC 2002). Based on the available data, the extent of effects on groundwater may be limited to the vicinity of these two wells.

Table 3-36 Summary of Groundwater Analysis Results for 1,2,3-Trichloropropane on Madera Ranch (μg/l)

Well	1999	2000	2001	2005	2006	2007
Section 1 (RW-1)	–	–	ND	–	–	–
Section 1 (RW-2)	0.07	0.24	0.02	0.5	0.41	0.22
Section 1 (RW-4)	–	–	0.05	0.17	0.19	ND
Section 4 (RW-21)	–	–	ND	–	–	–

Source: TRC 1999, 2002, 2007.
– = not applicable or not analyzed.

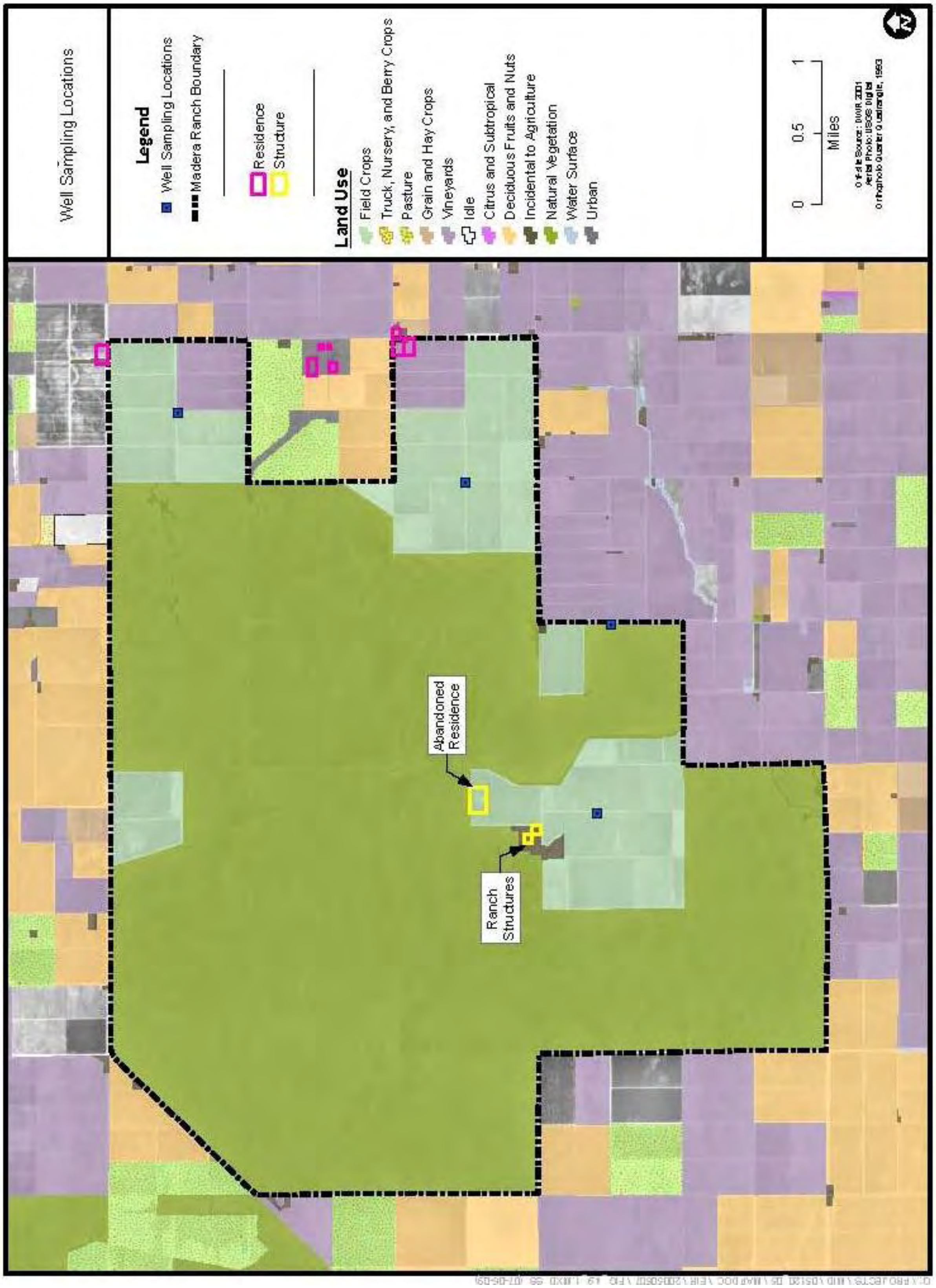


Figure 3-10 Well Sampling Locations

Four wells were tested for inorganic constituents in September 1999 (TRC 1999). Inorganic data presented in Table 3-37 show the relative chemistry of the groundwater at Madera Ranch. As indicated, no state or federal criteria were exceeded.

Table 3-37 Groundwater Results for Inorganic Constituents on Madera Ranch (mg/l)[a]

	Well Identification				
	Section 1 (RW2)[b]	Section 13 (RW7)[b]	Section 21 (RW20)[b]	Section 22 (RW16)[b]	Drinking Water Action Level Criteria
pH (standard units)	7.8	7.5	7.7	7.8	6.5–8.5[c]
Chloride (mg/L)	51.6	23.9	34.6	18.7	250[f]
Fluoride (mg/L)	<0.1	<0.1	<0.1	<0.1	2.4[d]
Nitrate nitrogen (mg/L)	3.5	2.5	3.5	1.6	10[d]
Sulfate (mg/L as SO_4)	9.5	26.5	15.6	11.3	250[e]
Bicarbonate (HCO_3)	134	156	264	143	NS
Carbonate (CO_3)	<2	<2	<2	<2	NS
Hydroxide	<2	<2	<2	<2	NS
Total alkalinity ($CaCo_3$)	134	156	264	143	NS
Hardness ($CaCO_3$)	180	180	280	120	NS
Specific conductance (µS/cm at 25ºC)	466	438	607	354	900[f]
TDS	309	313	411	265	500f
Aluminum	<0.05	<0.05	<0.05	<0.05	1[d]
Arsenic	<0.002	0.003	0.004	0.007	0.01[d]
Barium	0.14	0.14	0.18	0.078	1 [d]
Cadmium	<0.001	<0.001	<0.001	<0.001	0.005[d]
Calcium (as Ca)	37	37	58	24	NS
Chromium	<0.005	<0.005	<0.005	<0.006	0.05[c]
Copper	<0.005	<0.005	<0.005	<0.005	1[e]
Iron	<0.015	0.037	<0.015	0.024	0.3[e]
Lead	<0.005	<0.005	<0.005	<0.005	0.015[d]
Magnesium (as Mg)	12	12	15	6.7	NS
Mercury	<0.001	<0.001	<0.001	<0.001	0.002[d]
Selenium	<0.005	<0.005	<0.005	<0.005	0.05[d]
Silver	<0.005	<0.005	<0.005	<0.005	0.1[d]
Sodium (as Na)	30	29	46	37	NS
Zinc	<0.005	0.007	0.009	0.006	5[e]

Source: Bookman-Edmonston 2003.
NS = No existing primary or secondary MCL standard.
< = Value preceded by this sign indicates parameter was not detected above the method detection limit shown.
[a] Units are in mg/L unless otherwise noted (mg/L are equivalent to PPM).
[b] Ranch well: Monitoring wells (Figure 3-11).
[c] RWQCB, Basin Plan Amendment Criteria (1998).
[d] Primary MCL from California Code of Regulations (CCR) Title 22 (2004).
[e] Secondary MCL from CCR, Title 22, or from the U.S. EPA National Drinking Water Standards (2004).
[f] Recommended secondary MCL from the U.S. EPA National Drinking Water Standards (2004).

3.17.2 Environmental Consequences

Alternative A—No Action

Under the No Action Alternative there would be no adverse effects to water quality. However, the future conditions would change to support agricultural activities. The type and extent of water quality effects from agricultural activities would vary based on the type of activities conducted; these effects would be evaluated by the County under CEQA, depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect WQ-1: Degradation of Water Quality Resulting from Construction Runoff
Construction of the recharge ponds, upgrades of canals, and installation of the recovery wells and recovery system would require grading and excavation along with disturbances of soils and vegetation under Alternative B. Although construction would be intermittent, stormwater runoff could cause soil erosion of disturbed sites and transport other construction-related contaminants (e.g., fuels, oil, concrete, paint) to nearby receiving waters and thereby impair water quality and aquatic organisms and their habitats. The extent of the effect depends on soil erosion potential, type of construction practice, extent of disturbed area, timing of precipitation events, and proximity to drainage channels.

This effect is considered adverse. Environmental Commitments WQ-1a and WQ-1b would minimize the extent and intensity of effects.

Effect WQ-2: Water Quality Effects from Construction-Related Dewatering Discharge of water from construction-related dewatering during lift station construction and enlarging of the Section 8 Canal could result in the release of contaminants to surface water or groundwater. Primary construction-related contaminants that may reach groundwater would include sediment, oil and grease, and construction-related hazardous materials.

This effect would be considered adverse if the quality of water in the canal or underlying groundwater exceeded established standards as a result of construction activities. Implementation of Environmental Commitment WQ-2 would ensure that this potential effect does not occur.

Effect WQ-3: Potential Effects on Groundwater or Surface Water Quality from Recharge or Recovery Operations Recharge operations may increase the potential for water quality degradation as a result of dispersion of contaminants from uncontrolled flows or a spill upstream of MID's diversion points. If contaminants were to enter the aquifer and concentrate to a degree that violates water quality standards, a major effect would result. As described below, MID would continue surveillance operations of MID conveyances to ensure that contaminants from uncontrolled flows or spills upstream do not enter the recharge facilities.

Alternative B temporarily may increase TDS in the groundwater beneath the ranch as a result of short-term leaching of salts during recharge. TDS in the native groundwater beneath the Madera Ranch ranges from about 180 to 660 mg/L (as shown in Table 3-37). Recharge water allocated from the San Joaquin River and Fresno River would contain approximately 28 to 100 mg/L TDS (Tables 3-34 and 3-35). MID had three percolation studies performed and found that leaching of salts from the soil profile would be largely complete during the initial three- to four-month recharge season. They further concluded that the increase in TDS would be short-term, temporary, and localized. After the initial flushing of salts has occurred, TDS concentrations would begin to decline as the low TDS recharge water mixes with the higher TDS groundwater. Over the long term, it is expected that TDS concentrations in groundwater would drop below current levels. An additional factor reducing the potential effect of leaching salts is that the swale recharge areas were chosen specifically because they overlie the highest-permeability soils with the lowest salt concentrations in the Madera Ranch area. Taken together, over the long term, the recovered water is expected to be more reflective of the source water quality, which has lower TDS concentrations than the native groundwater. There would be no adverse effect on groundwater quality over the long term.

The MROC, as described Section 2, would be responsible for development and implementation of the MOCP, which includes:

- monitoring recovery operations to ensure that 10% of the banked water is left behind to help abate the overdraft;
- monitoring TDS in recovered water leaving Madera Ranch and in groundwater flowing away from Madera Ranch to ensure that water quality remains suitable for irrigation purposes;
- monitoring drinking water wells within one mile of Madera Ranch for fecal coliform, TDS, and select components of TDS as specified by the Oversight Committee;
- monitoring water levels in perimeter wells during recharge operations and shutting down recharge operations if off-site water levels rise to within 30 feet of the ground surface;
- monitoring water levels in off-site wells during recovery operations and adjusting operations, providing compensation, or providing an alternate source of water in the event that water levels drop to unacceptable levels in off-site wells as a consequence of operations; and
- ongoing surveillance of MID conveyances to ensure that if accidental spills of hazardous materials occur, they do not enter the recharge facilities.

Implementation of the MOCP would ensure that effects associated with spills or leached salts are avoided or minimized. This effect is not considered adverse.

Effect WQ-4: Potential Soil Salinization from Elevated Groundwater Levels (also in Geology section) Because Alternative B will be operated and constrained so that water tables affected would not reach elevations higher than 30 feet below the ground surface at the Madera Ranch site boundary, groundwater would not cause salinization of the root zones of important, deep-rooted agricultural crops surrounding the site. Therefore, there would be no effect.

Effect WQ-5: Potential Erosion Attributable to Reversal of Flows in 24.2 Canal and Cottonwood Creek/Main No. 2 Canal In Phase 2, MID is proposing to construct lift stations on 24.2 Canal and Cottonwood Creek/Main No. 2 Canal to provide as much as 100 cfs of pump-back delivery capacity. Recovered water would be pumped back up the 24.2 Canal between Avenue 10 and the Fresno River. Recovered water would be pumped back up Cottonwood Creek/Main No. 2 Canal between Road 23 and SR 99.

During existing MID operations, Cottonwood Creek commonly carries 300 cfs, and no adverse scouring or bank erosion has been noted (Howard pers. comm.). Because only as much as 100 cfs is expected with Alternative B and velocities would likely be one foot per second or less, no adverse scouring or bank erosion is expected. This effect is not considered adverse.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used (550 acres versus 700 acres as proposed under Alternative B) and a reduced number of recharge basins would be constructed (323 acres versus up to 1,000 acres under Alternative B). Reduced Alternative B would also exclude construction of the Section 8 canal southwest extension. Although Reduced Alternative B would use fewer swales and limits the number of recharge basins, thereby reducing effects associated with degradation of water quality resulting from construction runoff and from recharge or recovery operations (Effects WQ-1 and WQ-3), it would not result in changes to the quality of water sources or the overall patterns of water banking anticipated under Alternative B. With the implementation of the MOCP, Reduced Alternative B would result in similar effects (Effects WQ-1, WQ-2, WQ-3, WQ-4, and WQ-5), from construction and operation of the WSEP. Thus, water quality effects would be similar to those that would occur under Alternative B, and Effects WQ-1 and WQ-2 are considered adverse. Implementation of Environmental Commitments WQ-1a, WQ-1b, and WQ-2 would reduce the intensity of these effects.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. Thus, engineered basins would be built earlier in the design cycle than under Alternative B. This would not result in changes to water sources or the overall patterns of water banking anticipated under Alternative B and, with the implementation of the MOCP, would result in similar effects (Effects WQ-1, WQ-2, WQ-3, WQ-4, and WQ-5) resulting from construction and operation of the WSEP. Thus, water quality effects are considered equivalent to those that would occur under Alternative B, and Effects WQ-1 and WQ-2 are considered adverse. Implementation of Environmental Commitments WQ-1a, WQ-1b, and WQ-2 would reduce the intensity of these effects.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B. This would not result in changes to quality of the water sources or the overall patterns of water banking anticipated under Alternative B and, with the implementation of the MOCP, would result in similar effects (Effects WQ-1, WQ-2, WQ-3, and WQ-4). Use of GF Canal for conveyance does alter the pattern of dispersal of water into the bank but is not anticipated to alter the water quality characteristics of the bank. Effects resulting from reversal of flows (Effect WQ-5) still could occur but would occur on GF Canal (Effect WQ-6).

Thus, overall water quality effects are considered equivalent to those that would occur under Alternative B and are considered adverse. Implementation of Environmental Commitments WQ-1a, WQ-1b, and WQ-2 would reduce the intensity of these effects.

Effect WQ-6: Potential Erosion Attributable to Reversal of Flows in Gravelly Ford Canal
In Phase 2, MID is proposing to construct a lift station on GF Canal to provide as much as 200 cfs of pump-back delivery capacity. Recovered water would be pumped back up GF Canal to the San Joaquin River.

During existing GFWD operations, GF Canal always carries less than 200 cfs, and no adverse scouring or bank erosion has been noted (Dorrance pers. comm.). Under Alternative D, improvements to the GF Canal would be engineered to accommodate as much as 200 cfs with velocities of up to one foot per second, which is the highest flow that would occur under this alternative. Thus, no substantial scouring or bank erosion is expected. This effect is not considered adverse.

Cumulative Effects

Construction-related effects (WQ-1 and WQ-2) would have no regional water quality cumulative effect because environmental commitments included as part of Alternative B would be implemented to avoid impacts on water quality. Adverse water quality effects related to operations could have cumulative impacts within Madera County (Effects WQ-3, WQ-5, and WQ-6). Implementation of the MOCP (Madera Irrigation District 2007) and the ongoing activities of the MROC would ensure that local water quality effects are avoided and minimized. No additional activities are known to exist that would affect water quality in local canals and in the groundwater in and around Madera Ranch. Thus, no potential cumulative effects are anticipated for any of the alternatives (Alternatives B, C, and D).

3.18 Water Supply

The policies and regulations that govern Reclamation and the Corps must be taken into account in the analysis of the alternatives and in assessing potential effects on local or regional sources of surface water supply. MID's proposed operations would be subject to the conditions of MID's existing contracts with Reclamation and of MID's water rights.

The analysis of surface water resources and supply is based on a comparison of the range of historical diversions by MID to what is expected with the Proposed Action and alternatives. The analysis of groundwater resources and supply is based on an assessment of current groundwater basin conditions and expected conditions with the Proposed Action and alternatives.

3.18.1 Affected Environment

Sources of water for the Proposed Action and alternatives include MID's long-term water supply contracts with Reclamation (Friant Division supplies and Hidden Unit supplies), CVP non-storable uncontrolled flows delivered under temporary contract, and MID's pre-1914 water rights.

Friant Division Supplies

MID has a CVP water supply contract with Reclamation for delivery from the Friant Division of 85,000 AF/year of Class 1 water and 186,000 AF/year of Class 2 water, both for irrigation purposes (long-term renewal contract 175r-2891-D; December 29, 2010). Class 1 water is

–firm” supply, and Class 2 water is less reliable water that is dependent on seasonal runoff accumulating behind Friant Dam. Class 2 water may be available after all Class 1 obligations have been met. MID’s yield from all the water supply contracts averaged 167,342 AF/year during the period from 1985 to 2007. The long-term agricultural water supply contracts that supply water to the Madera area are summarized in Table 3-38.

Table 3-38 CVP Water Supply Contracts in Madera Area (AF/year)

Contractor	CVP Source	Class 1 Supply	Class 2 Supply	Other CVP Supplies
MID	Friant Division	85,000	186,000	
	Hidden Unit (from Hensley Lake on the Fresno River)			40,357 (average 1985–2007)
GFWD	Friant Division	–	14,000	
CWD	Friant Division	55,000	160,000	
	Buchanan Unit (from Eastman Lake on the Chowchilla River)		–	24,000
Madera County	Friant Division	200	–	

Notes:
GFWD = Gravelly Ford Water District.
CWD = Chowchilla Water District.
CVP = Central Valley Project.
– = no contract.

Water available from behind Friant Dam is diverted into the Madera Canal (for MID and CWD), the San Joaquin River (for GFWD), and the Friant-Kern Canal (for the remaining Friant contractors) (Figure 2-1). MID receives water from the Madera Canal through diversions into the district at the Lateral 6.2, Hildreth Creek (sporadically), the Fresno River (Lateral 18.8 with downstream diversion into the Main Canal), Dry Creek–Lateral 24.2, Berenda Creek, and at Lateral 32.2. Water for GFWD and several other users is released down the San Joaquin River for diversion at various points above Gravelly Ford.

However, the SJRRP, as described previously, would result in roughly a 25% decrease of water available from the Friant Division. The effects of this water supply reduction on MID water supply are described further under Historical and Proposed Diversions.

Hidden Unit Supplies

MID also has a contract with Reclamation that makes available for delivery to MID –the entire quantity of Project Water from Hidden Unit for irrigation purposes” (Long-Term Renewal Contract 14-06-200-4020A-E; December 29, 2010). The Hidden Unit includes CVP water stored or flowing through Hensley Lake on the Fresno River. The yield from the Hidden Unit has averaged 52,952 AF/year since 1992 (Dorrance pers. comm.). The Corps, which operates Hidden Dam/Hensley Lake, releases water down the Fresno River from Hensley Lake for diversion by MID into its Main Canal. The river typically is dry downstream of the MID diversion, although when flood control parameters have been exceeded, excess flows are released past the MID diversion. In some years, flows in excess of MID needs extend to the Eastside Bypass for short periods. MID also uses the Fresno River channel to convey Friant water from the Madera Canal to the Main Canal diversion.

Other Supplies

MID has pre-1914 water rights that average 7,938 AF/year from Big Creek and 7,719 AF/year from Soquel Creek (Dorrance pers. comm.). Water from Soquel Creek is regulated in Bass Lake and then flows into Millerton Lake and is diverted into the Madera Canal. Water from Big Creek is diverted through Hensley Lake.

Friant Section 215 water, which occasionally is available to MID, is CVP water that Reclamation determines is available at Friant Dam as the result of an unusually large water supply not otherwise storable for CVP purposes, or infrequent and otherwise-uncontrolled flows of short duration. MID must enter into a temporary contract with Reclamation, not to exceed 1 year, to obtain Friant Section 215 water.

Historical and Proposed Diversions

MID diverts an average of 167,342 AF/year (1985–2007) of surface water from the sources discussed above. Of that amount, an average of 102,756 AF/year (1985–2007) of surface water is delivered to district farmers. The remaining surface water, averaging 64,586 AF/year (1985–2007), has been recharged (with a small amount lost to evapotranspiration) through MID conveyances at eight existing percolation facilities, or incidentally recharged as a result of spills Table 3-39 provides details regarding historical availability of water for the bank with and without the estimated impact of the SJRRP on water supply. The presented data are based on continuous, daily, weekly, and monthly flow measurements by MID and Reclamation at various points of diversion and readings from more than 800 farm turnouts. This table includes estimated diversions of MID entitlements toward the SJRRP. Detailed notes on assumptions and calculations follow the table.

Table 3-39 Historical Availability of MID Water (AF)

Calendar Year[1]	Year Type[2]	MID Diversions[3]	Surface Water Delivered To MID Customers[4]	Water Sent to Existing Recharge Basins[5]	Required Carriage Water[6]	Water that would have been available for the Proposed Action[7]	Water that would have been available for the Proposed Action with River Restoration[8]
1985	D	133,630	85,234	NA	41,213	7,183	0
1986	W	318,478	149,426	NA	66,742	55,000	55,000
1987	C	95,138	58,414	NA	17,034	19,146	19,146
1988	C	84,777	53,718	NA	15,199	15,112	0
1989	C	102,883	61,411	NA	18,686	21,679	0
1990	C	72,094	46,402	NA	16,528	8,583	0
1991	C	116,052	79,583	NA	22,939	13,387	0
1992	C	95,956	61,967	NA	19,123	14,385	0
1993	W	263,134	154,367	5,192	58,352	45,223	45,223
1994	C	114,705	77,910	0	23,429	12,964	12,964
1995	W	343,754	128,351	4,310	65,778	55,000	55,000
1996	W	241,850	134,546	3,879	52,448	50,976	49,927
1997	W	247,374	150,356	3,665	49,646	41,189	33,409
1998	W	189,990	105,428	4,248	55,052	25,262	25,262
1999	AN	170,854	123,951	2,120	40,587	4,169	0
2000	AN	181,495	124,365	5,882	43,281	7,877	7,877
2001	D	147,584	108,150	805	28,996	9,274	0
2002	D	133,633	101,566	369	28,105	3,380	0
2003	BN	152,003	111,635	867	33,800	5,454	0
2004	D	136,998	107,696	0	29,303	0	0
2005	W	188,505	124,680	0	40,556	23,269	23,269
2006	W	193,742	116,660	3,956	46,056	27,070	27,070
2007	C	124,248	97,570	218	23,385	2,858	0
Annual Average		167,342	102,756	2,367	36,358	20,367	15,398
Total Volume Since 1985		**3,848,877**	**2,363,386**	**35,511**	**836,237**	**468,441**	**354,147**

NA = not applicable.

[1] MID performs water accounting on a calendar year basis.

[2] Year Type: W = Wet year type. AN = Above normal year type. BN = Below normal year type. D = Dry year type. C = Critical year type

[3] Diversions include transfers-in and MID Entitlements: Friant Class I, Friant Class II, Friant 215, Hidden Unit, Big Creek, North Fork Willow, and carryover of MID entitlements in Millerton Reservoir. It does not include: natural waters and other non-MID flows in creeks used in the MID distribution system; City of Madera run-off entering the MID distribution system; or Fresno River flows that were not diverted into the MID distribution system.

[4] As measured by MID.

[5] As measured by MID at Airport Pit, Burgess Pond, Allende Pond, Russell Pond, Dirt/Beeman Pit, Hospital Pond, and Pistoresi Pond. Deliveries to these locations were not formally measured by MID prior to 1993 but were generally minor for the period 1985-1992. MID also periodically sends water to Lake Madera, which is located adjacent to the Fresno River upstream of the MC&I intake. Consequently, these flows are not tracked in this spreadsheet and are excluded from Water that Would Have Been Available to the Project.

[6] Required Carriage Water includes normal operational conveyance recharge, evaporation, evapotranspiration, and water that flows out of the MID's distribution

Calendar Year[1]	Year Type[2]	MID Diversions[3]	Surface Water Delivered To MID Customers[4]	Water Sent to Existing Recharge Basins[5]	Required Carriage Water[6]	Water that would have been available for the Proposed Action[7]	Water that would have been available for the Proposed Action with River Restoration[8]

system back into the Fresno River and San Joaquin River. Normal conveyance recharge, evaporation, and evapotranspiration were calculated using 2004 as a benchmark year in which uncontrolled recharge was minimal and by back-calculating the amount of recharge per day that MID ran water in its system. This factor was then applied to other years adjusting for the actual number of days that MID ran water during those years.

[7] Water that Would Have Been Available to the Project represents MID entitlement water that was diverted, but not delivered to MID customers or to existing recharge basins or used as carriage water. Values in this column have been capped at 55,000 acre-feet because that is the annual recharge capacity of the Project. In years with transfers-in, the deductions for deliveries, recharge, and carriage water were adjusted downward using the ratio:
Diversions of MID Entitlements/(Diversions of MID Entitlements + Transfers-in).

[8] San Joaquin River restoration impact on available water was estimated by using the Steiner (September 2005) estimated reduction in MID Class 1 and 2 allocations for 1985–2004 and the averages for the year types of 2005–2007 as detailed in the Kondolf hydrographs used in the Stipulation of Settlement (September 2006). First, the Steiner reduction was reduced by the amount of Class 1 and 2 allocations that were not called by MID in that year because other cheaper water was available (e.g., 215 and uncontrolled flows). Under a River Restoration scenario MID would have called this water. Second, the total MID diversions for that year were reduced by the adjusted Steiner reduction. Third, the diverted water was allocated in the following order to stay consistent with the philosophy that MID will not reduce other uses and recharge as a consequence of the Proposed Action:

- First: Water required for conveyance recharge and ET (carriage water),
- Second: MID Farmer Deliveries
- Third: Water sent to existing recharge basins
- Fourth: Spill back to SJ and Fresno Rivers
- Fifth: Water Bank

The MID service area includes approximately 129,000 acres (more than 200 square miles) and approximately 417 miles of open-flow gravity conveyances, of which 192 miles are unlined and 225 miles are clay-lined (MID AB3030 Groundwater Management Plan prepared by Boyle Engineering 1999). The system does not include any telemetry or Supervisory Control and Data Acquisition systems to provide real-time adjustment of flows in response to changing conditions. Ditch tenders adjust flows in response to farmer demand by adding or removing boards from weir structures that are usually miles from locations where flow adjustment is required—resulting in significant lag times and inaccuracy. Historically, water that was not accounted for as delivered to farmers or sent to existing recharge basins or carriage water was attributable to:

- unauthorized diversions of MID's water for agricultural use;
- irregular, uncontrolled spills at a variety of locations that changed from month to month and year to year, depending on operational circumstances throughout the 200–square mile service area; and
- extended evaporative and seepage losses (above those indicated in the column titled Required Carriage Water) from conveyances that were filled to capacity and continued to hold water above immediate irrigation needs.
- The extensive conveyance system has been used as a form of temporary banking to accommodate uncontrolled flows and to allow greater flexibility in MID's deliveries.

In response to these conditions, MID's operations have become more efficient. Ditch tenders are required to be more responsive to farmers' demands and to curtail lag time and inaccuracies. In addition, MID has become more vigilant in preventing unauthorized diversions of its water supplies. Thus, MID is not proposing to increase the amount of water it diverts, reduce deliveries to farmers, or reduce deliveries to existing recharge basins, on average, and would be consistent with the SJRRP.

Table 3-39 details the historical availability of MID water that could have been banked, and conservatively excludes all water that returns to the Fresno and San Joaquin Rivers from diversions of MID's entitlements. This exclusion is conservative because non-MID water also is diverted by others into MID's conveyance system, such as uncontrolled flows and city of Madera runoff. Use of the conveyance system to control uncontrolled flows and runoff is likely to continue and is under the control of other agencies. MID has not included in Table 3-39 such flows as being available for the WSEP because it has no control over such operations. Further, it should be noted that MID uses an approximately 12-mile reach of the Fresno River to convey water from the Madera Canal and Hensley Lake to the main intake (MC&IC intake) of the MID distribution system. All losses and non-MID uses of water along this reach of the Fresno River have been excluded from the WSEP availability calculation.

Historically, there would have been water available for recharge in each of the last 22 years, with an average availability of 20,367 AF/year. Over the last 22 years, available water exceeded the proposed banking capacity of the WSEP.

However, the implementation of the SJRRP would result in a decrease in the supplies available to MID from the Friant Division. As such, the water that would be available for use by the

WSEP is less than what it would have been historically. The impact of the SJRRP on available water was estimated by using the Steiner (September 2005) estimated reduction in MID Class 1 and 2 allocations for 1985–2004 and the averages for the year types of 2005–2007 as detailed in the Kondolf hydrographs used in the Stipulation of Settlement (MID September 2006). Under the SJRRP, MID water would have been available for recharge in only 11 of the last 22 years (50% of the time), with an average availability of 15,398 AF/year. Thus, the majority of water that historically would have been available to the project (more than 75% over the period 1985–2007) would still be available after implementation of the San Joaquin River restoration settlement agreement. Other than this decrease in MID's entitlement to Friant Division supply, the SJRRP has no effect on the WSEP. State and federal agencies currently are evaluating the effects of the SJRRP in a program-level EIS/EIR.

Groundwater Hydrology

The WSEP is located in the Madera subbasin of the San Joaquin Valley groundwater basin. The total surface area of the subbasin is 394,000 acres or 614 square miles (California Department of Water Resources 2004). Surface water in the northern portion of the San Joaquin Valley, including MID's service area, is drained toward the Delta by the San Joaquin River and its tributaries. Surface water in the southern portion of the valley is drained internally by the Kings, Kaweah, Tule, and Kern Rivers, which flow into the Tulare drainage basin. Under natural conditions, these surface water flow patterns historically were mimicked by groundwater flows. Those conditions no longer prevail because of more than 100 years of intense groundwater pumping. The Madera subbasin (DWR Number 22.06) is bounded on the north by the Chowchilla subbasin (DWR Number 22.05), on the south by the Kings subbasin (DWR Number 22.08, separated by the San Joaquin River), on the west by the Delta-Mendota subbasin (DWR Number 22.07, separated by the San Joaquin River), and on the east by the crystalline bedrock of the Sierra Nevada foothills.

The Madera subbasin groundwater aquifer system consists of unconsolidated continental deposits, including older Tertiary and Quaternary age materials overlain by younger Quaternary deposits. Groundwater in the Madera subbasin is recharged by natural river and stream seepage, deep percolation of irrigation water, canal seepage, and intentional recharge. Groundwater flow is generally to the southwest in the eastern portion of the subbasin and to the northwest in the western portion. Locally, however, groundwater flow directions vary significantly because of the intense agricultural, municipal, and industrial groundwater pumping, which also has caused overdraft in a variety of locations, including the vicinity of Madera Ranch (Madera Irrigation District 1999; California Department of Water Resources 2004; Schmidt pers. comm.). The amount of groundwater pumping within the Madera subbasin varies from year to year, depending on the availability of MID surface water, precipitation, and temperature. In critically dry years, groundwater pumping can more than double over the amount of pumping during wet years.

As detailed in MID's AB3030 Groundwater Management Plan and in DWR's *Bulletin 118* (California Department of Water Resources 2004), the Madera subbasin has been subjected to severe long-term groundwater overdraft. A variety of overdraft estimates has been compiled for various portions of the basin. At the request of MID, Ken Schmidt and Associates compiled the results of these various efforts to estimate overdraft for the entire basin. Based on the compiled prior work and independent calculations, Schmidt estimated an average groundwater overdraft of

100,000 AF/year as of 2000 (Schmidt pers. comm.). The recent draft Integrated Regional Water Management Plan substantiated these findings and indicated overdraft could be as much as 200,000 AF/year by 2030 (Madera County 2008).

As depicted in Figure 3-11, groundwater levels in the Madera subbasin have declined an average of 67 feet since 1945 and 30 feet since 1980 (California Department of Water Resources 2005). Although there have been some years of slight recovery, the overall trend is downward. Similar groundwater level declines have occurred in the vicinity of Madera Ranch. Since 1943, groundwater levels beneath Madera Ranch and the surrounding area have declined at least 90 feet, and the trend remains downward.

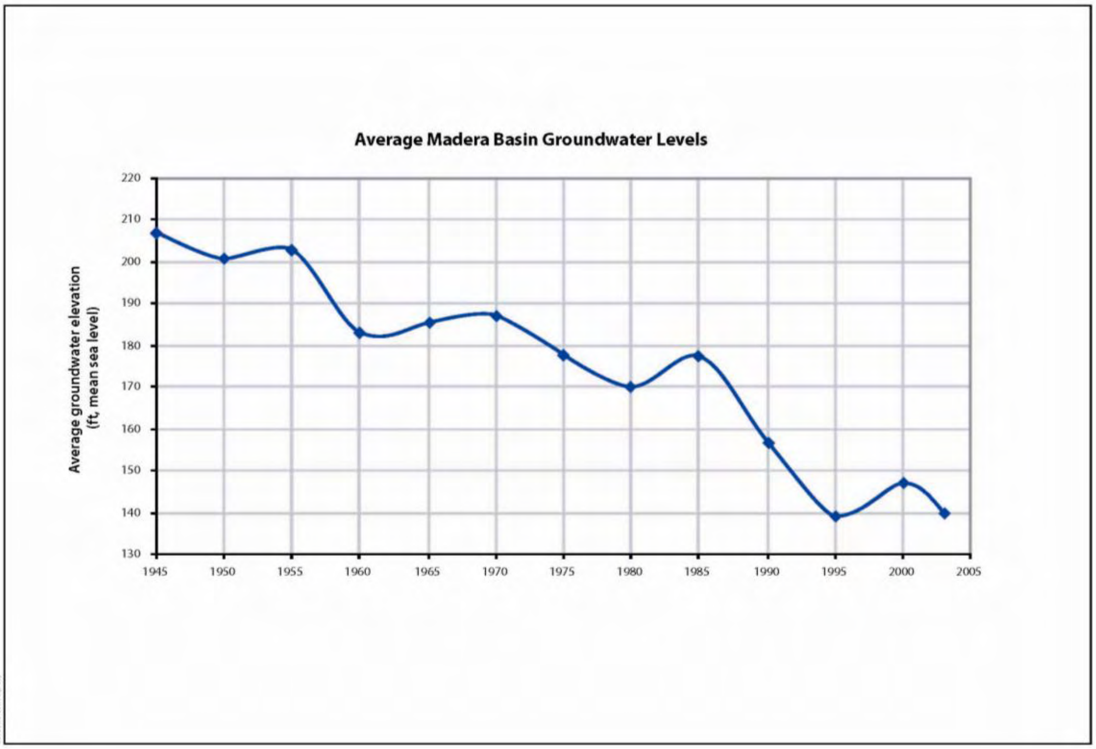


Figure 3-11 Historical Trends in Average Groundwater Levels in the Madera Subbasin

The available banking capacity in the dewatered aquifer beneath the Madera Ranch area (above the current water table) has been estimated to range from 286,720 to 573,440 AF, with 400,000 AF most commonly estimated (CALFED Bay-Delta Program 2000; Bureau of Reclamation 1998).

3.18.2 Environmental Consequences

The WSEP's design capacity is based on facilities to divert and convey as much as 200 cfs of water from either Friant Division or Hidden Unit operations to Madera Ranch for recharge. Recovered water would flow by gravity or be pumped to MID. Each of the alternatives, including the Proposed Action, specifies an annual recharge capacity of 55,000 AF/year. These specifications have been established for design purposes. The operating conditions and the ability to bank water would be determined primarily by:

- availability of wheeling capacity in the Madera Canal and MID conveyances,
- percolation rate and total area available to recharge the water,
- ability of the groundwater basin to bank and transmit water,
- hydrologic conditions that would influence the volume and timing of diversions of water for banking from the Friant Division or Hidden Unit operations,
- farmer irrigation demand in the pump-back area, and
- San Joaquin River restoration.

The effects of the alternatives on water supply and management are related primarily to the amount of water that would be diverted to local users. MID is not proposing to increase the amount of water it diverts; rather, the alternatives include banking a portion of the water that historically has been diverted.

Alternative A—No Action

Under the No Action Alternative, Reclamation would not approve the banking of CVP water outside MID's service area, nor would Reclamation issue an MP-620 permit, a Mid-Pacific Region-specific permit to approve modifications to its distribution system. Reclamation's No Action Alternative would have no adverse effects on water supply. However, the future conditions could change to support agricultural activities. The type and extent of water supply effects from agricultural activities would vary based on the type of activities conducted; in general increased agricultural operations would be expected to contribute to the groundwater overdraft situation in the County. These effects would be evaluated by MID or the County under CEQA depending on the discretionary permits needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect WS-1: Changes in Groundwater Supplies or Overdraft Rates in Madera County

MID proposes to limit water recovery to 90% of the water that is recharged at Madera Ranch under the Proposed Action. This limitation would ensure that the Proposed Action does not deplete groundwater supplies in Madera County but rather contributes to the reduction of the rate of groundwater overdraft over time. Compared to the current overdraft conditions, the Proposed Action would have only a slight benefit. However, over the life of the project, the reduction in the rate of overdraft would be a beneficial effect.

Effect WS-2: Substantial Effects on Surrounding Groundwater Wells as a Result of Recovery Operations Under Alternative B, approximately 40 new wells would be used to recover banked water. While the well field has been designed to draw from the mound of banked surface water, it is possible that this pumping could cause the water levels in surrounding wells to decline below levels that would occur absent Alternative B. As described in Chapter 2, the MROC will monitor water levels in perimeter wells and impose operational constraints to avoid or minimize effects. The MROC is responsible for implementation of the MOCP. The plan would include the following basic activities.

- Monitor recovery operations to ensure that 10% of the banked water is left behind to help alleviate overdraft.

- Monitor TDS in recovered water leaving Madera Ranch and in groundwater flowing away from Madera Ranch to ensure that water quality remains appropriate for irrigation purposes.
- Monitor drinking water wells within one mile of Alternative B for fecal coliform, TDS, and select components of TDS, as specified by the MROC.
- Monitor water levels in perimeter wells during recharge operations and shut down recharge operations in the event that off-site water levels rise to within 30 feet of the ground surface.
- Monitor water levels in off-site wells during recovery operations and adjust operations, provide compensation, or provide an alternate source of water in the event that water levels drop to unacceptable levels in off-site wells as a consequence of operations.
- Perform ongoing surveillance of MID conveyances to ensure that, if accidental spills of hazardous materials occur, these spills do not enter the recharge facilities.

Implementation of the MOCP would ensure that effects are avoided or minimized. This effect is not considered adverse.

Effect WS-3: Substantially Alter the Existing Drainage Pattern or Contribute to Existing Local or Regional Uncontrolled Flows Madera Ranch and the surrounding landscape are fairly level. Standard measures for erosion control and management of the stormwater runoff would be included in the construction plans for Alternative B, and, therefore, this alternative would not substantially alter any existing drainage pattern.

One thousand acres of recharge basins would be constructed within an area as large as 1,300 acres, although individual basin cells would be on the order of five–80 acres each. These basins would be excavated and some spoils would be used to form low berms to achieve an effective depth of approximately five feet to prevent wind-induced waves from overtopping the berms. Berm heights would vary, depending on topography, but would not exceed five feet.

DWR’s DSOD has developed criteria delineating its jurisdiction over impounded surface water bodies. Dams that meet jurisdictional coverage must meet specific safety and integrity requirements based on the risk associated with their potential failure. Water would be impounded in shallow excavations, and most of the berms would be lower than five feet and below the DSOD jurisdictional height limit of six feet. The nearest residence is approximately 0.75 mile away from the recharge basin window and outside the fenced ranch perimeter. Given the area between the recharge basins and residences, water escaping in the event of berm failure would pool on land between the Madera Ranch site and the residence. This effect is not considered adverse.

Effect WS-4: Adverse Effects on the Area of Origin of Water from Amendments to Existing Water Rights MID is not proposing to amend its existing water rights and is not proposing to buy water as part of Alternative B. Water exchanges between MID and other potential users would require additional analysis, but generally would include only water that historically was diverted for agricultural use or that previously has been exchanged between parties in a similar manner.

MID does intend to sell banking space to local M&I users. Banking capacity also could be reserved and used to help implement the SJRRP. MID would allocate 10,000 AF each for M&I and environmental water users in Madera County. M&I users are broadly evaluated in the section on Growth Inducing Effects. All potential users would require separate environmental approvals and would rely on their own water entitlements in using the proposed groundwater banking and recovery facilities. These exchanges would not reduce the availability of water in the area of origin. There is no effect.

Effect WS-5: Reduced Surface Water Availability in Madera County or the Area of Origin Alternative B does not involve diversion of water directly from the San Joaquin River or Fresno River to the water bank. Friant Division and Hidden Unit water would be diverted from the Millerton Lake and Hensley Lake, respectively, as MID has done historically, and then delivered to Madera Ranch. The quantities of water diverted would be within the range of historical diversions. There would be no direct influence on the San Joaquin River or Fresno River water availability or streamflows.

Nothing in Alternative B would allow MID or its participants to divert or transfer water out of the area of origin, and would not deprive those with legal rights or entitlements to the San Joaquin River or Fresno River from obtaining water supplies currently available. Alternative B does not include, nor seek changes to, water rights, in terms of type, place, or point of use, for water that originates in the San Joaquin River or Fresno River.

There are no known adverse water supply effects that would be associated with the proposed diversion of Class 1, Class 2, or Section 215 water because:

- this water is available as part of permitted operations of the Friant Division,
- reductions in diversions resulting from the SJRRP would not prohibit the bank from meeting MID or Reclamation’s purpose and need,
- operations are already conditioned under the existing Biological Opinion, and
- current facilities would be used.

Because these waters would be used within existing local service areas, Alternative B would not reduce local water supplies. In fact, it provides a net benefit in available water supplies to Madera County. Water reductions resulting from the SJRRP would reduce the average availability of water by roughly 25%. However, this reduction would not significantly inhibit MID’s ability to meet the water needs of the project because the SJRRP would not result in a reduction of water available in wet years (Table 3-39).

Thus, there would be no substantial adverse reduction in surface water availability in Madera County or the San Joaquin area of origin.

Effect WS-6: Water Supply Reliability Improvement in Dry Years Under Alternative B, up to 55,000 AF of banked water would be available in dry years. The actual amount available would depend on the amount of water banked in previous years. This would be an improvement in water supply reliability during dry years because the banked water would be used to offset supply reductions in dry years, thereby making supply more dependable in all year types. This would be a beneficial effect.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used and a reduced number of ponds would be constructed. This would not result in any differences from what was described above for Alternative B relative to changes to existing water rights or the overall method of water banking and, with the implementation of the MOCP, would result in nearly identical effects (Effects WS-1, WS-2, WS-3, WS-4, WS-5, and WS-6). Thus, water supply effects are considered identical to those that would occur under Alternative B and not considered adverse. Similar to Alternative B, groundwater overdraft reduction would be beneficial.

Alternative C—Water Banking outside the MID Service Area without Swales and Alteration of Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the primary exception that the natural swales that occur on the site would not be used for recharge. This would not result in any differences from what was described above for Alternative B relative to changes to existing water rights or the overall method of water banking and, with the implementation of the MOCP, would result in nearly identical effects (Effects WS-1, WS-2, WS-3, WS-4, WS-5, and WS-6). Thus, water supply effects are considered identical to those that would occur under Alternative B and not considered adverse. Similar to Alternative B, groundwater overdraft reduction would be beneficial.

Alternative D—Water Banking outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. This could result in substantial effects on existing water rights (Effect WS-7) or regional surface water availability (Effect WS-8) that does not occur under either Alternative B or Alternative C (Effects WS-4 and WS-5).

Alternative D still would result in beneficial effects on local groundwater supply (Effect WS-1) nearly identical to those that occur under Alternative B and would not adversely affect local groundwater wells and existing drainage patterns (Effects WS-2, WS-3, respectively).

Effect WS-7: Adverse Effects on the Area of Origin of Water from Amendments to Existing Water Rights MID is not proposing to amend its existing water rights and is not proposing to buy water as part of Alternative D. However, significant water exchanges would need to occur in order to facilitate the use of GF Canal as the primary conveyance route for water coming into and out of the bank. As water would not be able to be pumped back into MID's service area, MID would release water into the San Joaquin River in exchange for other water releases from the Friant Dam. Reclamation is the only feasible partner for such exchanges that would allow MID to bank its existing water right at Madera Ranch and then exchange that water for releases of SJRRP water into MID's service area.

MID does intend to sell banking capacity to local M&I users. Additional banking capacity also could be reserved and used to help implement the SJRRP in addition to water exchanges that would facilitate the functionality of Alternative D. Under Alternative B, MID would allocate 10,000 AF each for M&I and environmental water users in Madera County. M&I users are broadly evaluated in the Section on Growth Inducing Effects. All potential users would require separate environmental approvals and would rely on their own water entitlements in using the proposed groundwater banking and recovery facilities. None of the proposed exchanges would reduce the availability of water in the area of origin. There is no effect.

Effect WS-8: Reduced Surface Water Availability in Madera County or the Area of Origin
Alternative D would involve the diversion of water during wet years directly from the San Joaquin River to the water bank via GF Canal, and could therefore alter the flows in the river and by diverting water at the beginning of Reach 2. However, this diversion would be compliant with the flow requirements set forth under the Settlement, which has been developed to protect downstream beneficial uses. As shown in Table 3-39, MID would be able to bank available water during most wet years. During dry years, water would not be available to the bank, as it would be needed for restoration flows, and no diversions via GF Canal would occur.

Under Alternative D, MID could bank water during wet years without adversely affecting restoration flows. During dry years, MID would not bank and could make releases to the San Joaquin River for restoration flows in exchange for the delivery of restoration flows to MID users. The flow release schedule for the SJRRP calls for the release of 116,662 AF during critical low years, representing the smallest release under the Settlement. During the eight critical dry years during 1984–2007, MID surface water deliveries averaged 67,122 AF (with total diversions averaging 100,732 AF) and a maximum surface water delivery of 97,570 AF in 2007. Thus, settlement releases could be exchanged with MID deliveries, even in critical dry years. This trend holds true for deliveries under all water type conditions, and thus MID could exchange flows with the SJRRP releases without adverse effects on San Joaquin River flows. These exchanges would, in years that exchanges occur, allow Reclamation to achieve its flow objectives in Reach 2, but Reclamation still would be required to make releases to support five-cfs flows in Reach 1 (from Friant Dam to GF Canal). This would not represent an adverse effect on flows in the San Joaquin River as it would have no effect on the benchmarks necessary to meet the goals of the San Joaquin River Settlement. No loss of surface water is expected.

Additionally, nothing in Alternative D would allow MID or its participants to divert or transfer water out of the area of origin, and Alternative B would not deprive those with legal rights or entitlements to the San Joaquin River or Fresno River from obtaining water supplies currently available. Alternative D does not include, nor seek changes to, water rights in terms of type, place, or point of use, for water that originates in the San Joaquin River or Fresno River.

No known adverse water supply effects would be associated with the proposed diversion of Class 1, Class 2, or Section 215 water because additional supplies are not being requested and SJRRP would not diminish the effectiveness of the WSEP because:

- both MID's CVP supplies and the SJRRP water are available as part of permitted operations of the Friant Division,
- overall reductions in contract water and deliveries resulting from San Joaquin River restoration would not prohibit the bank from meeting MID or Reclamation's purpose and need,
- operations are already conditioned under the existing Biological Opinion(s) governing CVP operations, and
- current facilities would be used, and in several areas resized, to allow more operational flexibility.

Because these waters would be used within existing local service areas, Alternative D would not reduce local water supplies. It is anticipated that Alternative D would result in a net benefit in available water supplies to Madera County. Water reductions resulting from the SJRRP would reduce the average availability of water by roughly 15%. However, this reduction would not significantly reduce the water available for banking in the WSEP to the extent that the project would lose feasibility. San Joaquin River restoration would result in no reduction of water available in wet years (Table 3-39).

There would be no reduction in surface water availability in Madera County or the San Joaquin area of origin as a result of Alternative D. There is no effect.

Cumulative Effects

Adverse water supply effects related to operations could have cumulative impacts in Madera County (Effects WS-2, WS-3, and WS-8). Under all action alternatives, Effect WS-2 could cumulatively contribute to impacts on surrounding groundwater wells. However, implementation of the MOCP (Madera Irrigation District 2007) and the ongoing activities of the MROC should ensure that local groundwater supply effects are avoided and minimized. Additionally, the project does not contribute to the ongoing cumulative effect of groundwater overdraft but rather provides a benefit by limiting the amount of water recovered so that 10% of the water banked is left in the aquifer.

3.19 Wetlands

This section describes the existing wetland resources in the areas potentially affected by the proposed alternatives. It discusses the affected environment, relevant regulations and policies, methods of analysis, and possible effects.

The approach used to analyze effects of the Proposed Action on wetlands is to:

- conduct extensive surveys to document wetland resources on Madera Ranch;
- identify effect mechanisms to analyze effects of the alternatives; and
- determine the extent and duration of effects.

The wetland terminology used in this section is slightly different than the terminology used in the Biological Resources section. For example, freshwater marsh and ponds are treated as habitat types in the biological resources section because they have different wildlife habitat functions than other vegetation types. Under this section freshwater marsh, ponds, and swales that have water applied to them regularly are seasonal wetlands. Vegetation in these areas will fluctuate back and forth between grassland and wetland depending on the amount of water and area applied.

3.19.1 Affected Environment

MID consultants delineated waters of the United States at Madera Ranch by a combination of field surveys and aerial photograph interpretation. The initial wetland delineation was started in early 2000, with updates in late 2000, 2004, 2005, and 2009.

Wetlands were identified using the routine onsite determination procedure from the Corps wetlands delineation manual (Environmental Laboratory 1987). The 1987 manual provides technical guidelines and methods for determining the boundaries of jurisdictional wetlands based on three parameters: hydrophytic vegetation, hydric soils, and wetland hydrology. The wetland indicator of plant species was taken from the national list of plant species that occur in wetlands (Reed 1988). Although the study area was larger than five acres, the routine determination procedure was used instead of the comprehensive determination procedure because the areas of potential wetlands were small and widely scattered across the site. Sampling along regular transects would not have been an effective or efficient means for determining wetland boundaries.

Wetland delineators made hydrological observations on wetlands present at Madera Ranch during reconnaissance surveys on December 9, 1999; February 3, 2000; and March 10, 2000. Wetland hydrology was not observed directly for all wetlands at Madera Ranch. Instead, selected representative areas with evident wetland hydrology were noted, mapped, and marked as reference locations for later surveys. Photographs of wetland areas were taken during the March 10 site visit.

Wetland delineators revisited the study area on March 20, 21, and 22, 2000. Sample points were established at 14 representative locations throughout the study area. At each sample point, the dominant plant species within six feet of the sample point were recorded. A shallow soil pit (less than 18 inches deep) was excavated by hand at each sample point to compare soil characteristics with the mapped unit and to determine whether soils exhibited redoximorphic features. Data from each sample point were recorded on standard data forms.

From April 3 through April 7, 2000, biologists conducted vegetation surveys of the study area. Surveys were performed by walking line transects across each section at approximately 150-foot intervals and recording plant species and plant communities present. During this survey, the delineation study area was inspected, and all wetlands present were identified and mapped using the vegetation and hydrology indicators determined from the representative sample points.

Wetlands at Madera Ranch are seasonal and, as such, are a type of problem area (Environmental Laboratory 1987). At Madera Ranch, wetland hydrology is evident only during the rainy season (mid-October to mid-April). Because no rain fell between March 8 and April 13, wetland hydrology was not evident in most wetlands during the late March and April surveys. Corps guidelines for problem areas recommend that, when a wetland indicator is absent because of a normal seasonal variation in environmental conditions, a wetland delineator may determine the parameters of their survey based on personal ecological knowledge of the range of an area's normal environmental conditions. Wetland delineators inferred the presence of wetland hydrology during their late March and early April surveys by comparing each area they surveyed with the reference areas observed to have wetland hydrology during the February 3 and March 10 surveys.

The potential extent of Corps jurisdiction along Cottonwood Creek was determined by visual estimation of the ordinary high water mark (OHWM), defined as ―the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas" (33 CFR 328.3[e]).

Natural Resources Conservation Service/U.S. Army Corps of Engineers

Site Verification Visit in 2000 On June 27, 2000, the NRCS and Corps visited the site with the lead wetland delineator to verify the wetland delineation and stream mapping. It was determined that the delineation of Sections 15, 16, 17, 20, 21, 22, 28, and 29 was accurate and certified the delineation. For the purposes of the project that was contemplated at that time (a water bank), it was agreed upon that the remaining areas of the ranch could be delineated by photo interpretation for the purposes of planning and the Section 404 permit process.

Photo Interpretation in 2000 Wetlands in Sections 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, and 18 were delineated by aerial photography interpretation in 2000. Aerial photographs of the entire Madera Ranch were taken on March 15, 2000, by Aerial Photomapping Services of Clovis, California. Aerial photographs provided for the delineation were unrectified black and white prints (1 inch = 800 feet).

The photo signatures of potential wetlands in these sections were compared with the photo signatures of wetlands identified in the field survey study area. Standing water was visible in deeply ponding wetlands. Other wetlands produced characteristic photo signatures. Slickspots possess a high albedo and are readily apparent. Alkali rain pools were indicated by a darker signature corresponding to an area of saturated soil. Shallow vernal pools were indicated by sharply defined darker areas within the lighter grassland matrix, typically occurring within swales.

Site Verification Visit in 2004 On August 26, 2004, NRCS visited the site with the lead wetland delineator to verify the photo-interpreted portions of the project site. NRCS determined that additional data collection was needed before the delineation could be certified (Nielson pers. comm.). The Corps concurred with this assessment and also requested that additional data be collected (Norton pers. comm.). In response, additional field studies were undertaken in 2005 to collect data from the portions of Madera Ranch not field surveyed in 2000.

Field Surveys in 2005 In 2005, the delineation study area was expanded to include the sections evaluated in 2000 by aerial photography. Areas with apparent wetland photo signatures were field verified to confirm that wetland indicators were present. Data were collected from all sections of Madera Ranch and offsite locations where other activities would occur.

Wetland delineators made hydrological observations on wetlands in the northern sections of Madera Ranch during reconnaissance surveys on March 3, 4, 9, 10, and 11, 2005. Areas with wetland hydrology were noted and mapped as reference locations for later surveys. Wetland delineators revisited the study area on April 4, 5, 6, 14, and 15, 2005, to collect data from 85 additional sample points, primarily in the northern sections of Madera Ranch. Data collection methods were the same as in 2000.

Observations were also made at Cottonwood Creek, the West Lateral canal, the 24.2 Canal, the Section 8 Canal, and the Main #2 Canal on March 11, April 14, and July 12, 2005. Each canal was visually inspected to document the general characteristics and to evaluate it for potential Corps jurisdiction.

Photo Interpretation in 2008 During 2006, MID advanced a test project to determine the feasibility of using swales for groundwater recharge; this included letting agricultural tail-water spill into the swale in Section 14 and 15. This effort concluded use of the swales was feasible and preferable to pond construction because of cost. MID continued the effort in 2007. Also, between 2005 and 2008, several agricultural tenants changed as did the crop types being grown on the property. The new tenants also let agricultural water spill into swales in several locations on the property. Cottonwood Creek was allowed to spill into the bottom of Section 28 and 29 as it had historically, and the northern reach of GF Canal was also used during this period of time. Therefore, to update the delineation to reflect current site conditions, Consultants used one-half meter resolution imagery from Aerials Express (August 2006) and one meter resolution imagery from the National Agricultural Imagery Program (June 2005) to map artificial wetlands, Cottonwood Creek, GF Canal, and other interpretable canals. One-half meter imagery was used for most of the property and one-meter imagery was used for Sections 6, 7, 18, and the western 1/8th of Sections 5, 8, 17, 20, and 29. The features were digitized at a scales ranging from 1:2,000 (for half-meter photos) to 1:4,500 (for one-meter photos). The alkali rain pools and vernal pools appeared to be shifted with the new aerial photographs because they were previously digitized using un-rectified aerial photographs. Therefore, the pool locations were adjusted, using a GIS software rubber sheeting process, to overlay the registered 2005 and 2006 aerial photographs.

Site Verification Visit in 2009 On February 3, 2009, The Corps visited the site with Consultant staff to further assess Cottonwood Creek, GF Canal, and swales. As a result of this site visit, the Corps requested several additional revisions to the delineation.

Results and Discussion

The area of wetlands delineated at Madera Ranch include seasonal wetlands, GF Canal, Cottonwood Creek and many small, isolated vernal pools and alkali rain pools (including those previously delineated but affected by agricultural activities). Project elements within water bodies and uplands are summarized in Table 3-13 (located in the Biological Resources section). A discussion of the delineation results and a description of the wetlands and other waters are presented below.

Field Verification of 2000 Aerial Photography Interpretation Interpretation of aerial photography overestimated both the extent of alkali rain pools and the extent of vernal pools. The slightly darker photo signature apparent in some slick spots was found to be saturated soils, where the wet portions of the pools were in clear contrast with the lighter dry portions. However, a dark photo signature was also found to be present in some slick spots that do not pond, presumably because of a difference in soil chemistry from slickspots with light photo signatures.

Extensive areas with darker photo signatures in swales in Sections 10 and 11 were interpreted in 2000 as indicating the presence of large wetland areas. However, large areas of wetlands were not observed in these sections during the subsequent surveys. The darker signatures indicate both small vernal pools and wetter areas of annual grassland, areas that do not pond for a sufficiently long period to have wetland hydrology but that do have more vigorous plant growth than the adjacent, drier grassland.

General Hydrologic Observations Precipitation data for the 1999–2000 rainfall year was obtained from the California Irrigation Management Information System (CIMIS) station in Madera (MADERA.A, CIMIS station #145). Precipitation during the 1999–2000 rainfall year (July 1 to June 30) was near average (10.4 inches) as of May 18, 2000. However, the rainfall season was compressed within a short timeframe. Rainfall was less than 15% of average until mid-January. Most of the season's precipitation fell between mid-January and the first week of March.

During surveys on February 3, 2000, and March 10, 2000, ponding was observed in isolated wetlands. By February 3, rainfall was at 32.9% of normal. At that time, only the deeper wetlands were ponded. By March 10, rainfall was 85.1% of average and all areas subsequently delineated as wetlands were ponded.

Precipitation data for the 2004–2005 rainfall year is an average of the data from the MADERA.A and MADERA.T (Touchstone station #32) CIMIS stations. The amount and pattern of rainfall in 2004–2005 was substantially different than in 1999–2000. Precipitation during the 2004–2005 rainfall year was well above average, with 153% of normal rainfall as of May 31, 2005. By March 3, 2005, rainfall was 113% of normal. In addition, rainfall events were spread relatively evenly across the rainfall year, with weekly rainfall totals exceeding 0.7 inches in 10 weeks between late October and early May.

Precipitation was below average in 2005 at 8.52 inches, above average in 2006 at 11.4 inches, and below average in 2007 at 5.29 inches.

Changing Site Conditions

Recent application of agricultural tail-water to several locations throughout the property and a wet year during 2006 has resulted in some changed conditions on the property. The overall number of vernal pools on the property appears to have been reduced by inundation, and some have been recategorized from earlier mapping efforts. In general, the inundated vernal pools appear to be at low spots within existing swales and conveyances. Mapping in 2001 indicated the presence of vernal pools in GF Canal and at the southern portion of the property in Sections 28 and 29, and these areas have been recategorized because of their human influence and artificial hydrology. A November 2007 site visit confirmed that the swales in Section 2, 3, 14, and 15 continued to be used for agricultural tail-water.

Wetlands

Vernal Pools The area of vernal pools delineated in the field study area is 21.22 acres. Vernal pools occur in swales, primarily on soils mapped under the Pachappa series. A duripan is absent and wetland hydrology is maintained by the very slow permeability of the soil surface horizons. Holland (1978) reports that vernal pools are uncommon in the soil series group that includes the Pachappa series because there is no restrictive layer. Because vernal pools are so uncommon on this soil type, neither Holland (1986) nor Sawyer and Keeler-Wolf (1995) include this type of vernal pool in their plant community descriptions. Invertebrate biologists found vernal pool fairy shrimp, *Branchinecta lynchi*, in the vernal pools during surveys in 2000–2001, which indicates that the pH is between 6.8 and 7.6 (Jones & Stokes file information). Vernal pools at Madera Ranch meet all three wetland parameters: hydrophytic vegetation, hydric soils, and wetland hydrology.

Vegetation The pools on Madera Ranch are often dominated by Mediterranean barley, which is usually seen in vernal pools that pond for a relatively short time. Typical vernal pool endemics present in the pools include coyote thistle, Fremont's goldfields, California water-starwort, bracted popcorn flower, mousetails, Pacific foxtail, and American pillwort. The dominant plant species are usually or almost always found in wetlands. Therefore, vernal pool vegetation meets the criterion for hydrophytic vegetation.

Vernal Pool Soils Vernal pools in the study area exist primarily within shallow depressions located on nearly level to gently sloping swale-like landforms. Soils in these swale-like landforms are mapped primarily as various phases of the Pachappa series. Soils in vernal pools located within Pachappa soil map units typically had finer subsoil textures, yellower matrix hues, and lower matrix chromas than are characteristic for soils of the Pachappa series. Additionally, most of the vernal pool soils in these map units exhibited redoximorphic features that consisted of a few faint to moderately prominent iron concentrations and depletions in the surface A horizon and/or immediately above a fine-textured (i.e., sandy clay loam) subsoil horizon. Vernal pool soils located within Pachappa soil map units with low chroma matrix colors and/or redoximorphic iron concentrations and/or depletions within 14 inches of the soil surface meet the hydric soils criterion.

Vernal pool soils located within Cajon loamy sand with low chroma matrix colors within 10 inches of the soil surface meet the hydric soils criterion.

Hydrology Vernal pools at Madera Ranch are inundated for several weeks during the growing season and, therefore, have wetland hydrology. Wetland hydrology of Madera Ranch vernal pools clearly differs from the hydrology of typical vernal pools. Vernal pools generally are found on soils that have a subsoil restrictive layer – either a duripan, claypan, or both (Holland 1978). The restrictive layer creates a perched water table near the soil surface that regulates water levels in the pools (Hanes et al. 1990). Water lost to evaporation and transpiration is replaced by subsurface flow from the adjacent uplands.

At Madera Ranch, the vernal pool soils do not have an identifiable restrictive layer above which a perched water table is present. Ponding appears to be attributable to very low permeability at the soil surface or in the upper soil horizons. The vernal pools with longer ponding duration appear to have the most clay present in the soil, with a clay Bt horizon. The duration of ponding depends primarily on the amount and timing of rainfall. Unlike typical vernal pools, the duration of ponding in vernal pools at Madera Ranch is not affected by the total amount of rainfall during the rainy season because there is no restrictive layer in the lower soil horizons to prevent the excess water from percolating deep into the ground. Observations of ponding depth and duration in vernal pools in 2005 were essentially the same as those in 2000, despite the greater amount of precipitation and more regular rainfall pattern in 2005.

Some of the vernal pools adjacent to the agricultural areas have had their hydrology altered by irrigation runoff.

Wetland Assessment Vernal pools at Madera Ranch meet all three wetland parameters: hydrophytic vegetation, hydric soils, and wetland hydrology.

Alkali Rain Pools The area of alkali rain pools delineated in the field study area is 16.33 acres. Alkali rain pools have not been described in the ecological literature and appear to have been little studied. Consultants previously identified this habitat in Tulare County (Jones & Stokes Associates 1998). Alkali rain pools form in slickspots that pond water for a long time. Invertebrate biologists found Lindahl's fairy shrimp in the alkali rain pools during surveys in 2000–2001, which indicates that the pH ranges from 6.9 to 8.6 (Jones & Stokes file information). Alkali rain pools at Madera Ranch meet all three wetland parameters: hydrophytic vegetation, hydric soils, and wetland hydrology.

Vegetation Alkali rain pools have different vegetation, soils, and hydrology than vernal pools (soils and hydrology are discussed below). Alkali rain pool vegetation is sparse, concentrated on the pool margins and along soil cracks. In contrast, vegetation in vernal pools typically covers the entire pool bottom. Alkali rain pools lack plant species characteristic of vernal pools, such as those found in vernal pools at Madera Ranch. Instead, vegetation of alkali rain pools is composed of halophytic/alkali tolerant, mostly annual species. Dominant species include seepweed, alkali peppergrass, dwarf popcorn flower, California alkali grass, large-flowered sand spurry, and annual *Atriplex* species.

The dominant plant species are usually or almost always found in wetlands. Therefore, the alkali rain pool vegetation meets the hydrophytic vegetation criterion. Because of the low vegetation cover, an alkali rain pool might be classified not as a wetland, but as other water, similar to a mud flat or playa lake. However, alkali rain pools are small and a component of a grassland ecosystem. The overall landscape is terrestrial and vegetated, not aquatic and unvegetated, as in mud flats and playa lakes.

Soils Alkali rain pools form in slickspots, which are relatively shallow, sparsely vegetated depressions containing strongly saline-alkali soils (Reid et al. 1993). In the study area, they are interspersed on nearly level interswale landforms where soils are mapped as different phases and/or complexes of the Fresno, El Peco, and Dinuba series, all of which are strongly to slightly saline alkali and possess a carbonate silica cemented hardpan at depths ranging from 20 to 40 inches.

Soils in alkali rain pools generally lacked hydric soil indicators such as low chroma matrix colors and other redoximorphic features but often showed evidence of inundation, such as sediment deposits and mudcurls. The lack of hydric soil indicators in slickspots inundated for significant periods of time (i.e., alkali rain pools) may be partially the result of their high soluble salt content, which results in low plant density and low microbiological activity within the pool boundaries. Despite the lack of hydric soil indicators, the slickspot soils are classified on the Madera County Hydric Soils List as hydric because they meet Criterion 3 (i.e., they are ponded for a long duration or a very long duration during the growing season) of the list.

Hydrology Alkali rain pools at Madera Ranch are inundated for several weeks during the growing season and, therefore, have wetland hydrology. Wetland hydrology of alkali vernal pools also differs from that of typical vernal pools. Although the Fresno and El Peco species soils have a duripan, no perched water table was observed above it. Therefore, all ponding occurs at the soil surface, similar to vernal pools on Madera Ranch.

Several factors appear to be responsible for ponding. Slickspots that pond water have a compact surface crust with a platy structure, and the pores are largely vesicular; both of these factors reduce permeability (Reid et al. 1993). In addition, slickspots have been observed to possess higher clay content than the adjacent soil (Reid et al. 1993). High sodium levels may cause clay particles (that would otherwise be aggregated) in the upper part of the A horizon to deflocculate, causing soil pores to become ―plugged”. This reduces permeability to the point that water ponds on the soil surface.

In contrast, nonponding slickspots at Madera Ranch lacked a compact surface crust. The reason for this difference is unclear; perhaps nonponding slickspots have lower levels of clay. Alkali rain pools were often found along fence lines or roads, suggesting that soil compaction by cattle or vehicles may have a role in creating the surface crust.

The presence of shrimp exoskeletons, although not a standard wetland hydrology indicator when the delineation field work was performed, was a useful indicator of wetland hydrology for differentiating between alkali rain pools and nonponding slickspots. Free-swimming crustaceans, including seed shrimp (*Ostracoda*) and fairy shrimp (*Branchinecta* sp.), were observed in all vernal pools and alkali rain pools during the February 3 and March 10, 2000, surveys, and during the March 2005 surveys. Free-swimming crustaceans need two or more weeks of ponding to complete their life cycles. The presence of crustacean exoskeletons in dried pool basins indicates that inundation was present for two weeks or longer, sufficient time for these shrimp to live and reproduce.

Wetland Assessment Alkali rain pools at Madera Ranch meet all three wetland parameters: hydrophytic vegetation, hydric soils, and wetland hydrology.

Seasonal Wetlands The delineation indicates there could be approximately 153 acres of seasonal wetlands on site. This number has varied over time and will continue to vary based on the amount and duration of application of additional water via agricultural tail-water or banking. Seasonal wetlands are observable from aerial photos in Sections 2, 3, 14, 15, 16, 20, 22, 28 and 29. These areas primarily have this classification because they have the hydrology component of wetlands. In many instances wetland soils are not present and there is limited wetland vegetation. Their primary function is grassland, except when they are wetted. Wetlands in the northern swales in Section 2 were classified as seasonal wetlands rather than vernal pools because they do not provide the functions and values of vernal pool habitat. Wetland hydrology of the northern swales is artificial and results from irrigation runoff or pumping of water into the swales for stock watering. During the wetlands reconnaissance of Madera Ranch and the botanical survey conducted in 2000, Consultants observed ponded areas at several locations along the northern swale and subsequently mapped these areas as vernal pools. In 2005, during the wetland delineation work to ground-truth areas delineated in 2000 by photointerpretation, only the easternmost portion of the northern swale exhibited ponding and that most of the swale did not appear to have been inundated recently. Vegetation in the swale consisted of upland grasses and forbs, and the soils did not exhibit hydric soil indicators. During subsequent site visits, Project consultants again observed input of irrigation water and dominance by weedy wetland species, including smartweed (*Polygonum* sp.). Because the water source is not rainfall based and plant species normally associated with vernal pools were absent, these wetlands are best classified as seasonal wetlands.

Wetlands west of Cottonwood Creek at the south end of Section 28 were characterized as vernal pools during the original wetland delineation in 2000. Although the wetlands were not dominated by vernal pool endemics, they were in shallow depressions. One of the dominant wetland species was water chickweed (*Montia fontana*), a wetlands generalist; other vernal pool endemics were not found. Although Project consultants observed drift lines in the swale adjacent to the pools, they were unaware that the swales received periodic inflows from Cottonwood Creek. In 2005, Project consultants observed that the area of inundation was much greater and of longer duration than had been observed in 2000, and perennial wetland vegetation, including rushes (*Juncus* spp.) had become established. Aerial photographs from 2006 indicate a continuation of this trend. The source of the wetland hydrology was overflow from Cottonwood Creek, the bank of which had been breached to redirect flood flows into the swale at the south end of Sections 28 and 29. In a 2009 site visit the west berm of the creek had been reconstructed, though MID indicates this area will continue to flood during high flow events. Because the hydrology is not rainfall based and vernal pool endemics were absent, these wetlands are best classified as seasonal wetlands.

The small pond located in the southeastern corner of Section 28 was also classified as a seasonal wetland. The basin is vegetated by vernal pool species and ruderal wetland species characteristic of disturbed seasonal wetlands, such as stock ponds or detention basins. A stand of riparian woodland is present around the margins. The pond was inundated during the April 2000 surveys. Based on the presence of hydrophytic vegetation and wetland hydrology, a wetland is present in the basin. However, this is an artificially maintained wetland.

The pond is connected to Cottonwood Creek via a culvert, and inflow is controlled by a gate valve. Therefore, the wetland hydrology is artificially maintained. If the inflows were discontinued, there is no reason to expect that wetland hydrology would continue. Other deeply excavated areas on Madera Ranch (e.g., Sections 16, 18, and the northern section of GF Canal) do not pond and do not exhibit wetland hydrology.

A second small pond is present along the eastern edge of Section 2. This pond was unvegetated at the time of the surveys in 2000. The wetland hydrology is artificially maintained by pumping water into the pond.

Other Waters

Other waters were delineated only on the Madera Ranch property. However, other waters in the vicinity of Madera Ranch were evaluated for their jurisdictional status.

Cottonwood Creek Cottonwood Creek is a natural stream that has been channelized along portions of its length. The channel has been deepened and widened by excavation. It is used to convey irrigation water from the Main No. 2 Canal and also conveys flood water during storm events. Cottonwood Creek becomes channelized approximately 2.75 miles east of Madera Ranch, near Road 22. Cottonwood Creek crosses Madera Ranch at the southwest corner of Section 28. The extent of Cottonwood Creek on Madera Ranch was delineated on the basis of its OHWM. The mean width of Cottonwood Creek within the OHWM on Madera Ranch is approximately 40 feet.

Cottonwood Creek continues west to just before the Eastside Bypass (approximately 7 miles west of Madera Ranch), where it turns north, paralleling the Bypass in a 15- to 20-foot-wide channel that is separated from the bypass by a levee. The channel showed evidence of having standing water, but no evidence of scour. Hydrophytes are present, at least in places, in the channel. It eventually flows into the Fresno River at Latitude 36.97695 degrees north, Longitude 120.366670 degree west.

Although historically it may have been a tributary of a water of the United States, Cottonwood Creek (an ephemeral flowing water body) does not currently appear to have a hydrological connection to the Fresno River under normal circumstances. As noted above, the creek has been channelized and realigned, conveying mainly irrigation water and, at times during the rainy season, runoff from surrounding areas and ditches. Such flooding and high flows, however, are rare in Cottonwood Creek, as indicated by the lack of channel scour, because of storage in local reservoirs such as Bass Lake, Millerton Lake, and Hensley Lake. Only in response to very extreme rainfall events does water flow the 15.5 miles from Madera Ranch to Cottonwood Creek's connection to the Fresno River. According to the Maintenance Supervisor for the Lower San Joaquin Levee District, Cottonwood Creek might connect to the Fresno River once every 10 years (Batey pers. comm.).

Canals

Gravelly Ford Canal GF Canal is a flat-bottom earth-lined channel that conveys irrigation water from the San Joaquin River to Madera Ranch. GF Canal and Cottonwood Creek share a quarter-mile reach of channel in the northeast quarter of Section 27. Flow into the northern reach of GF Canal is via a flow control structure on Cottonwood Creek. Flow is one-way; water conveyed via GF Canal is directed onto crops. The portion of the channel north of the ranch road along the boundary between Sections 16 and 21 was thought to have been abandoned during earlier versions of the delineation, but has conveyed flows in recent years. Freshwater marsh is present in the portion of the channel immediately north of the ranch road. Other portions of the canal north of the ranch road are vegetated by annual grassland and seasonal wetlands.

24.2 Canal The 24.2 Canal is an earth-lined channel that conveys irrigation water to areas east of Madera Ranch. Flow is one-way; water conveyed via the 24.2 Canal is directed onto crops or into the Main No. 1 Canal, which flows into the Main No. 8 Canal. The canal terminates in agricultural land.

Section 8 Canal The Section 8 Canal is an earth-lined channel that conveys irrigation water from the Main No. 1 Canal and Main No. 2 Canal (via Cottonwood Creek) to the east side of Madera Ranch. Flow is one-way; water conveyed via the Section 8 Canal is directed onto crops, and any surplus runoff is directed into swales, where it percolates into the ground. The canal terminates in agricultural land.

24.2–19.5 West Lateral Canal The 24.2–19.5 West Lateral Canal is an earth-lined channel that conveys irrigation water from the 24.2 Canal to the northeast corner of Madera Ranch. Flow is one-way; water conveyed via the 24.2–19.5 West Lateral Canal is directed onto crops, and any surplus runoff is directed into swales, where it percolates into the ground. The canal terminates in agricultural land.

Main No. 2 Canal The Main No. 2 Canal originates at the Madera Main Canal. It connects and terminates with Cottonwood Creek east of Road 25.

Uplands

Two grassland plant communities are present: California annual grassland and alkali grassland. Alkali grassland, which occurs on strongly saline-alkali soils, is discussed below. Slickspots are scattered within the grasslands. Few slickspots occur within California annual grassland; most occur within alkali grassland and are discussed in the ―Alkali Grassland" section.

California Annual Grassland Vegetation California annual grassland is the typical grassland community of the California Central Valley and adjacent foothills, composed of non-native annual grasses and forbs (Sawyer and Keeler-Wolf 1995). California annual grassland is the most widespread plant community at Madera Ranch, occurring in most uncultivated areas on the ranch, in both uplands and swales.

The dominant species in California annual grassland usually are not found in wetlands. Therefore, California annual grassland does not meet the hydrophytic vegetation criterion.

Soils California annual grassland occurs on Pachappa-Grangeville soils and on the slightly saline-alkali Fresno-El Peco soils. In the study area, soil samples in California annual grassland were generally restricted to the swales. The soils in the swales differed from soils of the Pachappa series in that they often possessed fine textured (i.e., sandy clay loam) subsoil horizons. The moderately sandy clay loam subsoil horizons were also found in vernal pools but at shallower depths than those in the grasslands. Soils in California annual grassland were not classified as hydric because they typically lacked the low chroma matrix colors and other redoximorphic features observed in the vernal pool soils.

Hydrology On March 10, 2000, and in March 2005, when wetlands on Madera Ranch were observed to be inundated, no inundation or soil saturation was observed in California annual grassland. No other wetland hydrology indicators were observed.

Wetland Assessment California annual grassland at Madera Ranch lacks all three wetland parameters: hydrophytic vegetation, hydric soils, and wetland hydrology.

Alkali Grassland Vegetation On Madera Ranch, alkali grassland is intermediate between typical California annual grassland and Valley sink scrub or Valley saltbush scrub (Holland 1986) communities. In Valley sink scrub, iodine bush (*Allenrolfea occidentalis*) is the dominant perennial shrub, and cover of annual grasses and forbs is generally low. At Madera Ranch, Valley saltbush scrub occurs only in the northern half of Section 7, outside the study area. In addition to the typical grassland species cited above, perennial and halophytic species are common. Perennial species present in the alkali grasslands include interior goldenbush, locoweed, alkali sacaton, and saltgrass. Slickspots are common and have a fringe of annual halophytic species, as described above for alkali rain pools.

In alkali grasslands that occur on clay soils, such as in the northern San Joaquin Valley, the vegetation is dominated by halophytic species that usually are found in wetlands (Jones & Stokes Associates 1990). At Madera Ranch, however, alkali grassland is dominated by species that are usually not found in wetlands. Hydrophytic or halophytic species are present but constitute a small percentage of the composition and cover. Therefore, alkali grassland on Madera Ranch does not meet the criterion for hydrophytic vegetation.

Soils Soils in alkali grassland are mapped as Fresno, El Peco, or Dinuba series and are moderately to strongly saline-alkali. Characteristics of soil samples taken in alkali grassland match those reported for those soils in the soil survey report. These soils were not classified as hydric because they lacked hydric soil indicators and were not classified as hydric on the Madera County Hydric Soils List.

Soils examined at sample points located within slickspots typically had finer textures and shallower hardpans than are characteristic for soils of the Fresno, El Peco, or Dinuba series. Soils in slickspots generally lacked hydric soil indicators such as low chroma matrix colors and other redoximorphic features. Slickspot soils were not classified as hydric because they lacked hydric soil indicators and were not classified as hydric on the Madera County Hydric Soils List.

Hydrology On March 10, 2000, and March 2005, when wetlands on Madera Ranch were observed to be inundated, no inundation or soil saturation was observed in alkali grassland or in slickspots. No other wetland hydrology indicators were observed.

Wetland Assessment Alkali grassland at Madera Ranch lacks all three wetland parameters: hydrophytic vegetation, hydric soils, and wetland hydrology. The slickspots were fringed by hydrophytic vegetation but lacked hydric soils and wetland hydrology.

Cultivated Lands

Cultivated lands at Madera Ranch include: all of Sections 1, 13, and 21; the northeast quarter of Section 4; the east half of Section 14; the southeastern quarter of Section 16; the northeastern quarter of Section 22; and, the portion of Section 22 west of the GF Canal. These cultivated areas are planted in alfalfa or corn and lack native vegetation except along the margins of roadsides and fence lines. Soils in the cultivated areas have been modified by cultivation and mostly were not examined in detail. Historically, the soils in the cultivated areas were mapped primarily as Fresno, El Peco, and Pachappa series. The cultivated areas appear to have been leveled at some time prior to this survey. On March 10, 2000, and in March 2005, when wetlands on Madera Ranch were observed to be inundated, no inundation or soil saturation was observed on cultivated lands.

Any wetlands that were present in the cultivated areas were converted to cropland before the passage of the Farm Security Act in 1985. Section 21 has been cultivated longer than any other section on Madera Ranch; it has been farmed since the mid-1960s. Section 22 was tilled and dryland cropped intermittently from the late 1960s until the early 1980s. Sections 16 and 17 contained center pivots for irrigated pasture and crops in the mid-1970s (Loquaci pers. comm.). The south half of Section 15 and a portion of Section 17 were also cultivated for between 10 and 15 years, starting around 1970, but are no longer cultivated. Therefore, any wetlands formerly present in the cultivated areas would be prior converted wetlands. No farmed wetlands are present in the cultivated areas.

3.19.2 Environmental Consequences

The Proposed Action could affect up to approximately 2,100 acres of Madera Ranch. Of this amount, approximately 130 acres currently are cultivated. MID would deliver surface water to approximately 700 acres of swales on a seasonal basis and would construct canals, ditches, and pipelines to convey the water to and from its facilities on Madera Ranch. MID would drill wells, install pump heads, and construct lift stations on the 24.2 Canal and the Main No. 2 Canal to deliver recovered water back into MID's system. As needed, MID would construct as much as approximately 1,000 acres of engineered recharge basins to supplement the recharge capacity of the swales (Figure 3-5). Effects on seasonal wetlands of the Alternative B, Reduced Alternative B, and Alternative C are similar as approximately 150 acres of swales mapped as seasonal wetland would continue to be inundated. Alternative D includes the inundation of approximately 45 acres of seasonal wetlands because fewer swales would be used to bank water. Inundation of an additional 400 acres (Reduced Alternative B) and 550 acres (Alternative B and Alternative C) of swale areas would result in the greatest effect to vernal pools and alkali rain pools under Alternative B (5.9 acres) and Alternative D (5.9 acres), followed by Reduced Alternative B (1.7 acres), and Alternative C (0 acres). For all alternatives, temporary construction would affect approximately one acre of alkali rain pools and less than 0.5 acre of vernal pools, and permanent construction would affect up to approximately two acres of alkali rain pools and no vernal pools.

Project elements within water bodies and uplands are summarized in Table 3-40.

Table 3-40 Project Elements within and near Water Bodies

Project Elements	U.S. Water Subject to CWA 404	Approximate Length/ Surface Area/Cut/Fill
Proposed Water Body Components		
Section 8 Canal, Cottonwood Creek, and Main No. 1 Canal Connection Upgrade (Section 8 Canal/Cottonwood Creek Connection)	Yes	250 lf cut
Gravelly Ford Canal Sedimentation Basin and Flow Regulation Area (Weir #1)	Yes	500 sf
Gravelly Ford Canal Flow Control Weir at Cottonwood Creek (Weir #2)	Yes	500 sf
Cottonwood Creek overflow improvements (rock slope protection)	Yes	350 lf
Reconditioning of existing canals and ditches (canal maintenance)	Yes	Excavation to previous shape
Reconditioning of existing canals and ditches (canal maintenance)	Yes	75 sf each
Cottonwood Creek Lift Stations	Yes	500 sf each
Gravelly Ford Canal Section 21 Northern/Western Laterals	Yes	100 sf
Gravelly Ford Canal Section 22 Southern Lateral	Yes	100 sf
Canal turnouts (seven new turnouts, two turnout replacements)	Yes	75 sf (0.04 ac) each
Wildlife crossings for Gravelly Ford Canal (three crossings)	Yes	1,018 sf (88 cy) each
Other Components within and near Water Bodies		
24.2 Canal improvements	No	36,000 cy excavation; (1.75 mile expanded and 0.75 mile new)
Section 8 Canal upgrades/extensions	No	76,000 cy excavation; (1.75 mile expanded, 1.75 mile existing to pipe, and multiple new extensions)
Use of swales for recharge[1] [2]	No	No cut or fill. <6 acres vernal pool/alkali rain pool from use of swales (Alternative B) and <2 acres for Reduced Alternative B
55 acres of recharge basins in agricultural lands	No	55 acres
Recharge basins in grasslands	No	Varies
Recovery wells	No	<0.1 acre/well
Recovery pipelines and electrical facilities [3]	No	<1.5 ac vernal pool/alkali rain pools from corridors

Notes: CWA = Clean Water Act; lf = linear feet; sf = square feet; cy = cubic yards.
[1] Vernal pools are located in swales and are subject to review under ESA Section 7.
[2] Swales not used for recharge under Alternative C. See Table 3-12 for vernal pool/alkali rain pool effects under each Alternative.
[3] Alternatives B, Reduced Alternative B, C, and D are the same for recovery facilities because the layout does not change.

The Proposed Action also may cause indirect effects. Indirect effects occur later in time or are farther removed in distance but must be predictable and reasonably certain to occur in order to be assessed. Potential mechanisms of indirect effects on wetlands include:

- changes in hydrology, such as altered patterns of runoff or changes to the surface water retention pattern and capacity and elevation of the perched water table;
- erosion and sedimentation that result from grading and other activities that remove vegetation; and
- water quality effects from contaminants such as road runoff or pesticides.

The activities described above can result in both permanent and temporary effects. Effects were characterized as permanent if they would result in the conversion of wetlands for the life of the Proposed Action. The extent of permanent and temporary effects on wetlands at Madera Ranch was estimated by overlaying the outline of proposed recharge basins, canals/ditches, extraction wells, pipelines, and maintenance roads (proposed footprint) on the map of wetlands. The footprint for the buried pipelines, maintenance roads, and canals/ditches is estimated to be a linear corridor 10 feet wide. The proposed footprint for the extraction wells is estimated to be 0.1 acre each.

Alternative A—No Action

Under the No Action Alternative there would be no adverse effects on wetlands. However, the total extent of seasonal wetlands could decrease depending on how the water is managed on Madera Ranch and if MID continues to bank its pre-1914 water. The future conditions would continue to support agricultural activities; the type and extent of the activities is uncertain at this time. Future owners would be subject to comply with CESA and ESA and the effects may be evaluated by the County under CEQA if discretionary permits are needed.

Alternative B—Water Banking outside the MID Service Area Using Swales and Alteration of Reclamation-Owned Facilities

Effect WET-1: Permanent Removal of Vernal Pools and Alkali Rain Pools during Construction, Operation, and Maintenance Construction of the proposed recharge basins, canals/ditches, extraction wells, pipelines, and maintenance roads would occur more than 250 feet from vernal pools and alkali rain pools. However, a possibility remains that these wetlands could experience both direct (construction of permanent facilities, compaction of soils) and indirect (changes to nearby hydrogeology or introduction of sediment) disturbances. In several instances, vernal pools are located within the swales proposed for operation. Flooding swales on a seasonal basis could result in degradation of vernal pool habitat for vernal pools within the swales. This effect is considered to be adverse. Implementation of Environmental Commitments BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal and Alkali Rain Pools and BIO-2b: Create, Restore, or Preserve Vernal Pools would minimize the extent of and compensate for adverse effects associated with Alternative B.

Effect WET-2: Other Wetland Effects during Construction, Operation, and Maintenance
Implementation of the Proposed Action would result in minor amounts of fill of waters of the United States subject to Corps jurisdiction under the CWA during installation of the weirs along Cottonwood Creek and improvements to GF Canal. Additionally, excavation is expected to occur where the Section 8 Canal connects with Cottonwood Creek. No construction-related impacts on wetlands are expected in the swales or constructed basin. The total amount of fill is still being evaluated by the Corps based on the project description, preliminary engineering designs, and relationship of project elements to waters of the United States and is expected to be

less than five acres. No substantial effects are expected to occur during construction along Cottonwood Creek because there are limited wetlands in this area. In GF Canal there are seasonal wetlands, including approximately two acres of freshwater marsh that would be affected. These effects would be offset by the development of freshwater marsh within GF Canal during operation and formation of seasonal wetlands within the swales during banking. Direct or indirect effects could occur on vernal pools and alkali rain pools, as described above in Effect WET-1.

Operational effects associated with the banking of water in the swales likely would increase the acreage of seasonal wetlands that occur on Madera Ranch. This acreage will fluctuate based on the water year type and length of time water is banked in the swales. This increase in seasonal wetlands is expected to result in greater wetland functions and values on site that could benefit waterfowl. No maintenance is proposed within the swales, and therefore no adverse operational effects are expected to occur in the swales. Maintenance of the canals periodically may result in the removal of wetland features that grow during operational periods. No substantial operational effects are expected to occur because no maintenance is proposed in the swales, limited wetland resources are expected to develop within the canals, and wetlands within in the canals would retain their previous functions after maintenance. As such, construction and operational effects on wetlands are not adverse.

Reduced Alternative B—Water Banking Outside the MID Service Area Using Select Swales and Alteration of Reclamation-Owned Facilities

Reduced Alternative B is similar in scope and design to Alternative B, with the primary exception that a reduced number of natural swales would be used in order to minimize effects to vernal pools, and a reduced number of ponds would be constructed. Reduced Alternative B also directs recharge activities in the swales on a priority basis to help avoid effects to vernal pools. As with Alternative B it would complete the water bank in two phases. Phase 1 would involve constructing necessary delivery infrastructure improvements (except for the Section 8 canal southwest extension), using select natural swales for recharge (550 acres versus 700 acres as proposed under Alternative B), and installing approximately five soil berms to direct recharge flows (the berms would be placed to avoid fill of wetlands). Phase 2 would involve constructing a limited number of recharge basins (323 acres versus up to 1,000 acres under Alternative B) and facilities for recovery of banked water. The reduced footprint of recharge basins and number of swales proposed under Reduced Alternative B would reduce the temporary and permanent construction effects on wetlands discussed under Alternative B (Effects WET-1 and WET-2). Environmental Commitments BIO-2a and BIO-2b would reduce the adverse Effect WET-1.

Alternative C—Water Banking Outside the MID Service Area without Swales and Alteration to Reclamation-Owned Facilities

Alternative C is similar in scope and design to Alternative B, with the exception that recharge is achieved using engineered recharge basins in lieu of the natural swales that occur on the site. Thus, engineered basins would be built in Phase 1 instead of using the swales in Phase 1 under Alternative B. The total amount of seasonal wetlands would decrease under this alternative because water would no longer be applied to any swales. This is not considered an adverse effect because these areas primarily function as grassland. The expected footprint of recharge basins under Alternative B would be identical to the maximum build-out of Phase 2 of

Alternative B and would result in nearly identical temporary and permanent construction effects on wetlands (Effects WET-1 and WET-2) and Environmental Commitments BIO-2a and BIO-2b would reduce the adverse Effect WET-1.

Alternative D—Water Banking Outside the MID Service Area with Banking and Recovery via Gravelly Ford Canal

Alternative D is similar in scope and design to Alternative B, with the exception that water would be conveyed to the site via GF Canal. For this reason, one recharge basin would not be built under Alternative D that was proposed under Alternative B. The majority of the swales proposed under Alternative C would also be used (less approximately 100 acres), and the expected footprint of recharge basins under Phase 2 of Alternative D would be nearly identical to Phase 2 of Alternative B. Alternative D would result in nearly identical temporary and permanent construction effects on wetlands as Alternative B (Effects WET-1 and WET-2). However, the extent of wetlands that could be affected could be greater under Alternative D because of the increased disturbance to GF Canal. However, as described under Effect WET-2, this effect is not adverse. The Environmental Commitments associated with Effect WET-1 are still appropriate and applicable.

Cumulative Effects

Effect WET-3: Cumulative Loss of Wetlands The WSEP would result in a minor conversion of wetlands (no more than five acres for any of the alternatives). At the same time, the use of swales for alternatives B and D have the potential to increase wetlands on Madera Ranch depending on the specific operations. Other projects, such as development and projects proposed in the County, have the potential to also convert wetlands, while banking efforts could result in increased wetlands. Overall, wetland loss in the region and throughout California is substantial, but regulatory programs and other efforts generally ensure no net loss of wetlands. Each of the alternatives includes commitments to offset wetlands loss attributable to the project, and therefore, there would be no cumulative effect.

Section 4 Consultation and Coordination

4.1 Coordination with other Agencies

Both the Corps and USFWS are cooperating agencies and provided comments to Reclamation at various stages in the EIS process. The Corps verified the preliminary wetland delineation provided by MID on November 13, 2009, and MID sought permits for reshaping existing drainage ditches and adding structures in artificial canals. Reclamation submitted a biological assessment to the USFWS for the WESP in April 2008, which analyzed Alternative B. The USFWS has provided two insufficiency memos requesting additional information on the project and Reclamation has responded to these memos. The USFWS's comments related primarily to avoiding and minimizing effects on federally listed species that may use the swales and associated habitat on Madera Ranch. On May 13, 2009, Reclamation responded to USFWS's request. From May 2009 to July 2010, Reclamation, MID representatives, USFWS, Corps, DFG and EPA met to modify the project description in order to meet the Least Environmentally Damaging Practicable Alternative, pursuant to section 404 of the CWA. In January of 2011, Reclamation provided a revised biological assessment to the USFWS, which analyzed Reduced Alternative B.

4.2 Public Outreach Process

This section describes the scoping and public outreach process that was followed for the MID WSEP Draft EIS. The public outreach efforts were conducted in accordance with NEPA to determine the focus and content of this EIS, and to solicit and consider the views of federal, state, and local agencies, and the general public regarding the scope and content of the environmental analyses contained in the MID WSEP Draft EIS. These efforts are described here.

4.2.1 Notice of Intent

Pursuant to the requirements of NEPA, Reclamation published a Notice of Intent to prepare a Draft EIS and Notice of Public Scoping Meetings in the *Federal Register* on September 28, 2007. The Notice of Intent was circulated to the public, local, state, and federal agencies, and other interested parties to solicit comments on the MID WSEP Proposed Action.

4.2.2 Scoping Process

NEPA requires a formal scoping process for the preparation of an EIS (40 CFR 1501.7). The main objective of the scoping process is to provide the public and potentially affected resource agencies with information on the alternatives and to solicit public input regarding the issues and concerns that should be evaluated in the environmental documentation. The scoping process is generally intended to provide Reclamation with information regarding the range of actions, alternatives, resource issues, and mitigation measures that are to be analyzed in depth in the EIS and to eliminate from detailed study those issues found not to be significant.

The scoping process for the MID WSEP Proposed Action was conducted to elicit comments from public agencies, other interested organizations and the public on the scope of the potential environmental effects and issues to be addressed in the Draft EIS. Reclamation and MID held EIS scoping meetings at MID's offices in Madera on October 22 and 29, 2007. Before the meetings, public notices were posted at MID's offices and published in the *Madera Tribune* and the *Fresno Bee* announcing the time, date, location, and purpose of the meetings. Each scoping meeting included an overview of the meeting's purpose, the Proposed Action and alternatives, potentially significant environmental issues, and opportunities for future public involvement. Attendees were given the opportunity to provide both oral and written comments. Only one verbal comment was made and a summary of that comment is included in Appendix A.

4.3 Draft EIS Availability

Pursuant to NEPA, the Draft EIS was made available for a 60-day public review period from July 24, 2009 to September 25, 2009. A notice of availability of the Draft EIS was published in the *Federal Register* July 27, 2009. The purpose of the notice was to inform interested parties of the availability of the Draft EIS for public review and comment. Reclamation also issued a press release on its website to notify persons about the public meeting and sent written notice to all agencies and individuals on the MID WSEP Draft EIS mailing list.

Copies of the Draft EIS were made available for public review at Reclamation, Denver Office Library; Natural Resources Library, U.S. Department of the Interior; Reclamation, Mid-Pacific Regional Office Library; the South-Central California Area Office of Reclamation, Fresno, California; Madera Library, Madera, California; Chowchilla Library, Chowchilla, California; Madera Ranchos Library, Madera, California; Fresno County Public Library, Fresno, California; and Clovis Regional Library, Clovis, California.

In addition, an electronic copy was made available on the Reclamation web site at: http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=3128

The public comment period on the Draft EIS closed September 25, 2009. Written comments were received from two federal agencies, three state agencies, and four other entities and are included in Appendix A. Comments (verbal and written) pertained to the following topics (Appendix A):

- potential impacts on water quality,
- potential impacts on water supply,
- potential water rights issues,
- potential impacts on biological resources, and
- socioeconomic concerns related to economic impacts on farmers.

NEPA requires agencies to respond to comments on the Draft EIS that are received during the public comment period (President's CEQ Regulations for Implementing NEPA Section 1503.4). This document has been prepared pursuant to these requirements. Reclamation has considered all the verbal and written comments received on the Draft EIS and has determined the Draft EIS requires some changes to the Proposed Action. Responses to comments are also included in Appendix A.

The public agencies that provided comments on the Draft EIS include:

- United States EPA
- RWQCB, Central Valley Region
- DFG
- Corps
- California Farm Bureau Federation

Reclamation will provide copies of the Final EIS to these agencies.

4.4 Regulatory Environment

The Proposed Action must comply with the following Federal Regulations:

4.4.1 Clean Air Act

The federal CAA was enacted to protect and enhance the nation's air quality in order to promote public health and welfare and the productive capacity of the nation's population (42 U.S.C. 85). The CAA requires an evaluation of any federal action to determine its potential impact on air quality in the project region.

Federal Conformity Requirements

The CAA Amendments of 1990 require that all federally funded projects are consistent with the plan or program that conforms to the appropriate SIP. Federal actions are subject to either the transportation conformity rule (40 CFR 51[T]), which applies to federal highway or transit projects, or the general conformity rule.

The purpose of the general conformity rule is to ensure that federal projects conform to applicable SIPs so that they do not interfere with strategies employed to attain the NAAQS. As described in the Air Quality section, each of the alternatives would conform to the applicable SIP. Table 2.2 describes the environmental commitments to implement the SJVAPCD Regulation VIII Control Measures for construction emissions of PM_{10}, to reduce emissions associated with idling equipment and for the use of electric pumps.

4.4.2 Federal Endangered Species Act

Section 7 of the ESA requires federal agencies, in consultation with the Secretary of the Interior and/or Commerce, to ensure that their actions do not jeopardize the continued existence of endangered or threatened species, or result in the destruction or adverse modification of the critical habitat of these species. In addition, Section 9 of ESA prohibits removing, digging up, cutting, and maliciously damaging or destroying federally listed plants on sites under federal jurisdiction or doing so on nonfederal land in violation of any state law or regulation. Moreover, under Section 7 of ESA, federal agencies are prohibited from jeopardizing the continued existence of any federally listed species as a result of taking an action. Thus, the Section 7 process protects federally listed plants from the adverse effects of federal actions.

As described previously, Reclamation submitted a revised biological assessment as part of the formal consultation process with the USFWS. The USFWS issued a Final Biological Opinion on April 26, 2011 (Appendix B). Table 2.2 and Section 2 describe the environmental commitments required for compliance to the Biological Opinion.

4.4.3 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) requires that public and private entities consult with fish and wildlife agencies (federal and state) on specific water development projects that could affect fish and wildlife resources. The amendments enacted in 1946 require consultation with the USFWS and State fish and wildlife agencies ―whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, the channel deepened, or the stream or other body of water otherwise controlled or modified for any purpose whatever, including navigation and drainage, by any department or agency of the United States, or by any public or private agency under Federal permit or license". Consultation is to be undertaken for the purpose of ―preventing the loss of and damage to wildlife resources". CEQ regulations, §1502.25 (a) requires that ―…. agencies shall prepare draft environmental impact statements concurrently with and integrated with environmental impact analyses and related surveys and studies required by the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.), the National Historic Preservation Act of 1966 (16 U.S.C. 470 et seq.), the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), and other environmental review laws and executive orders."

As required by both FWCA and NEPA, Reclamation initiated early involvement with both USFWS and CDFG to obtain their recommendations on fish and wildlife resources, giving those recommendations equal consideration with respect to the project purpose and need. The Final EIS describes action-related effects to wildlife resources and identifies alternative means and measures necessary to enhance or mitigate impacts to wildlife resources. Because FWS was a cooperating agency, Reclamation consulted with CDFG, and all recommendations for wildlife enhancement were fully considered by Reclamation, this EIS provides Reclamations compliance with the FWCA.

4.4.4 Migratory Bird Treaty Act

The MBTA (16 U.S.C. 703 et seq.) implements various treaties and conventions among the United States, Canada, Japan, Mexico, and the former Soviet Union for the protection of migratory birds. Unless permitted by regulations, the MBTA makes it unlawful to pursue, hunt, take, capture, or kill; attempt to take, capture or kill; possess, offer to or sell, barter, purchase, deliver, or cause to be shipped, exported, imported, transported, carried or received any migratory bird, part, nest, egg or product, manufactured or not. Subject to limitations of the MBTA, the Secretary of the Interior may adopt regulations determining the extent to which these activities may be allowed, having regard for temperature zones, distribution, abundance, economic value, breeding habits, and migratory flight patterns. Preconstruction surveys and avoidance measures for western burrowing owls and other raptors would ensure compliance with the MBTA (Table 2-2).

Executive Order 13186—MTBA Responsibilities of Federal Agencies

EO 13186 directs federal agencies to take certain actions to further implement the MBTA. Each federal agency taking actions that have, or are likely to have, a measurable negative effect on migratory bird populations was directed to develop and implement, within two years of the order date (January 10, 2001), a Memorandum of Understanding (MOU) with the USFWS to promote the conservation of migratory bird populations. Reclamation has not signed an MOU with the USFWS regarding migratory birds. After a review of EO 13186, it was determined that, at that time, no MOU was appropriate. Nevertheless, the order states that notwithstanding the requirement to finalize an MOU within two years, each federal agency is encouraged to immediately begin implementing the conservation measures set forth in the order, as appropriate and practical. The preservation of grassland under conservation easement would aid in conserving potentially affected western burrowing owls and raptors (Table 2-2).

4.4.5 Bald and Golden Eagle Protection Act

The BGEPA prohibits the taking or possession of and commerce in bald and golden eagles, with limited exceptions. BGEPA makes it unlawful for any person to take, possess, sell, purchase, barter, offer to sell or purchase or barter, transport, export, or import at any time or in any manner a bald or golden eagle, alive or dead; or any part, nest, or egg of these eagles; or violate any permit or regulations issued under BGEPA. ―Take" includes pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest, or disturb. Transport includes convey or carry by any means and also deliver or receive for conveyance. The golden eagle is known to forage on Madera Ranch but does not nest there. As a result, there is no risk of take of golden eagles as defined under the BGEPA. Bald eagles are unlikely to use Madera Ranch, but if they do, they would only forage on the site and would therefore not be impacted (Table 2-2).

4.4.6 National Historic Preservation Act

Section 106 of the NHPA (15 U.S.C. 470 *et seq*.) requires that federal agencies evaluate the effects of federal undertakings on historical, archeological, and cultural resources and provide opportunities for the Advisory Council on Historic Preservation to comment on the proposed undertaking. The first step in the process is to identify cultural resources eligible for inclusion in the NRHP that are located in or near the project area. The second step is to identify the possible effects of the proposed federal actions. The lead agency must examine whether there are feasible alternatives that would avoid such effects. If an effect cannot reasonably be avoided, measures must be taken to minimize or mitigate potential adverse effects. The physical disturbance of undiscovered cultural resources could occur during construction; however, implementation of Environmental Commitment CR-1 (Table 2.2) to stop construction if cultural resources are discovered would reduce the intensity of the effect. As described in the Cultural Resource section, there would be no impacts to cultural resources.

Reclamation requested SHPO concurrence on a finding of no historic properties affected. SHPO agreed with Reclamation's findings on August 31, 2009, and concurrence was received August 31, 2009 (Appendix E). However, since that time, a number of additional activities have been proposed which require expanding the APE as described in the Cultural Resources section.

These areas and activities were not included in the original SHPO consultation package. Additional site surveys of this area were conducted on March 7-8, 2011 and no previously unknown cultural resources were identified. An updated memorandum (Appendix F) was prepared by consulting archaeologists.

4.4.7 Clean Water Act

Federal water quality regulations are established primarily in the CWA and administered by the EPA. These regulations are subsequently implemented primarily by the State Water Resources Control Board, Corps and other state agencies as deemed appropriate.

Several sections of the CWA pertain to regulating effects on waters of the United States. Section 101 specifies the objectives of CWA implemented largely through Title III (Standards and Enforcement) and Section 301 (Prohibitions). The discharge of dredged or fill material into waters of the United States is subject to permitting specified under Title IV (Permits and Licenses) of CWA and specifically under Section 404 of the act (Discharges of Dredge or Fill Material). Section 401 (Certification) specifies additional requirements for permit review, particularly at the state level.

Section 401

Under CWA Section 401, applicants for a federal license or permit to conduct activities that may result in the discharge of a pollutant into waters of the United States must obtain certification from the state in which the discharge would originate or, if appropriate, from the interstate water pollution control agency with jurisdiction over affected waters at the point where the discharge would originate. Therefore, all projects that have a federal component and may affect state water quality (including projects that require federal agency approval [such as issuance of a Section 404 permit]) must also comply with CWA Section 401. In California, the authority to grant water quality certification has been delegated to the State Water Resources Control Board, and applications for water quality certification under CWA Section 401 are typically processed by the RWQCB with local jurisdiction. Water quality certification requires evaluation of potential impacts in light of water quality standards and CWA Section 404 criteria governing discharge of dredged and fill materials into waters of the United States. MID coordinated with the Corps facilitated by Reclamation to determine if waters of the United States would be affected. A permit for compliance to Section 401 of the CWA certification; General Permit for Storm Water Discharges Associated with Construction Activity (CWA Section 402) is required.

Section 402—National Pollutant Discharge Elimination System Program

The 1972 amendments to the federal Water Pollution Control Act established the NPDES permit program to regulate discharges of pollutants from point sources (Section 402). The 1987 amendments to CWA created a new section of CWA devoted to stormwater permitting. The EPA has granted the state primacy in administering and enforcing the provisions of the CWA and the NPDES permit program. The NPDES permit program is the primary federal program that regulates point-source and nonpoint-source discharges to waters of the United States. The State Water Resources Control Board issues both general and individual permits for certain activities. A NPDES General Permit for storm water discharges associated with construction activity is required under Section 402.

Section 404

Section 404 of the CWA regulates the discharge of dredged or fill material into waters of the United States. Under Section 404, the Corps is responsible for issuing permits authorizing the placement of dredged or fill materials into jurisdictional water of the United States. MID coordinated with the Corps to ensure that effects on waters are minimized. A Section 404 Permit for discharges associated with construction activity is required.

4.4.8 Federal Flood Insurance Program

Congress passed the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. The intent of these acts was to reduce the need for large, publicly funded flood control structures and disaster relief by restricting development on floodplains.

FEMA administers the National Flood Insurance Program to provide subsidized flood insurance to communities that comply with FEMA regulations limiting development in floodplains. FEMA issues flood insurance rate maps for communities participating in the National Flood Insurance Program. These maps delineate flood hazard zones in the community. The WSEP does not include any development that would increase risk to people or property as a result of uncontrolled flows.

4.4.9 Executive Order 11988 – Floodplain Management

EO 11988 (May 24, 1977) requires federal agencies to prepare floodplain assessments for proposed actions located in or affecting floodplains. If an agency proposes to conduct an action in a floodplain, it must consider alternatives to avoid adverse effects and incompatible development in the floodplain. If the only practical alternative involves siting in a floodplain, the agency must minimize potential harm to or in the floodplain and explain why the action is proposed in the floodplain. The WSEP would be located within a floodplain, but would not affect the capacity of the floodplain or increase risk to people or property.

4.4.10 Executive Order 11990 – Protection of Wetlands

EO 11990 (May 24, 1977) requires federal agencies to prepare wetland assessments for proposed actions located in or affecting wetlands. Agencies must avoid undertaking new construction in wetlands unless no practical alternative is available and the Proposed Action includes all practical measures to minimize harm to wetlands. MID coordinated with the Corps to ensure that effects on wetlands are minimized. Table 2.2 describes the environmental commitments required for compliance to EO 11990.

4.4.11 Executive Order 12898 – Environmental Justice

EO 12898 (February 11, 1994) requires federal agencies to identify and address adverse human health or environmental effects of federal programs, policies, and activities that could be disproportionately high on minority and low-income populations. Federal agencies must ensure that federal programs or activities do not directly or indirectly result in discrimination on the basis of race, color, or national origin. Federal agencies must provide opportunities for input into the NEPA process by affected communities and must evaluate the potentially significant and adverse environmental effects of proposed actions on minority and low-income communities during environmental document preparation. Even if a proposed federal project would not result in adverse effects on minority and low-income populations, the environmental document must describe how EO 12898 was addressed during the NEPA process. As described in the Environmental Justice section, there would be no disproportionately high adverse impacts on minority and low-income populations.

4.4.12 Executive Order 13007 – Indian Sacred Sites and April 29, 1994, Executive Memorandum

EO 13007 (May 24, 1996) requires federal agencies with land management responsibilities to accommodate access to and ceremonial use of Indian sacred sites by Indian religious practitioners and avoid adversely affecting the physical integrity of such sacred sites. Where appropriate, agencies are to maintain the confidentiality of sacred sites. Among other things, federal agencies must provide reasonable notice of proposed actions or land management policies that may restrict future access to or ceremonial use of, or adversely affect the physical integrity of, sacred sites. The agencies must comply with the April 29, 1994, Executive Memorandum, *Government-to-Government Relations with Native American Tribal Governments*. No sacred sites are known to exist on or near facilities or other aspects of the project that would be affected by the WSEP.

4.4.13 Farmland Protection Policy Act and Memorandum on Farmland Preservation

Two policies require federal agencies to include assessments of the potential effects of a proposed project on prime and unique farmland. These policies are the Farmland Protection Policy Act and the Memoranda on Farmland Preservation, dated August 30, 1976, and August 11, 1980, respectively, from the CEQ. Under requirements set forth in these policies, federal agencies must determine these effects before taking any action that could result in converting designated prime or unique farmland for nonagricultural purposes. If implementing a project would adversely affect farmland preservation, the agencies must consider alternative actions to lessen those effects. Federal agencies also must ensure that their programs, to the extent practicable, are compatible with state, local, and private programs to protect farmland. The NRCS is the federal agency responsible for ensuring that these laws and policies are followed.

MID has consulted with the NRCS and has evaluated potential impacts to agricultural land using the land evaluation and site assessment process. The rating assigned by the NRCS for the loss of prime farmland identifies this loss as adverse. Environmental commitments to establish conservation easements on agricultural land are included to reduce the intensity of this effect (Table 2.2).

4.4.14 Service Area under Madera Irrigation District's Contracts

MID needs Reclamation approval for banking of CVP water in lands outside MID's service area. MID is coordinating with Reclamation in preparing this EIS and would obtain Reclamation approval through the ROD before implementing the Proposed Action.

Groundwater recharge programs are provided for under MID's contracts with Reclamation, as long as they are consistent with applicable state and federal law and are described in MID's Water Conservation Plan. MID has included the proposed WSEP in its 2005 update to its Water Conservation Plan. Under the Proposed Action, MID proposes to bank diversions that remain available following deliveries to farmers and deliveries to existing recharge basins (in a manner comparable to past operations) and after accounting for normal conveyance losses. For the Proposed Action, there would not need to be any water right amendments or applications. MID could only bank the water that they are already able to divert and use

Exchanges of CVP Water under Madera Irrigation District's Contracts

MID's contracts with Reclamation require prior written approval from Reclamation before an exchange can be implemented. The water banking space provided by the Proposed Action could facilitate a range of water exchanges among MID, GFWD, Chowchilla Water District, and potentially other water users in Madera County. For exchanges to proceed, additional environmental analysis would be necessary to ensure the direct, indirect, and cumulative effects of the exchange are addressed. Several examples of potential exchanges follow. GFWD has a Class 2 entitlement that could be delivered to Madera Ranch for recharge and water banking. As much as 90% of the banked water (minus conveyance losses) then could be delivered directly back to GFWD through existing conveyance facilities (e.g., GF Canal and Cottonwood Creek) or through an exchange. Similarly, Chowchilla Water District, which has both Class 1 and Class 2 water entitlements, could exchange water with MID farmers in lieu of their normal deliveries from Millerton Lake, thereby making an equal volume of water available in Millerton Lake for delivery to Chowchilla Water District through the San Joaquin River in the same fashion as used currently.

MID or other exchange participants would coordinate with Reclamation regarding any exchanges and would obtain Reclamation approval prior to implementation.

4.4.15 State Water Resources Control Board

Under the California Water Code, the State Water Resources Control Board is responsible for allocating surface water rights and permitting diversion and use of water throughout the state. The two most common types of surface water rights in California are riparian and appropriative. Through its Division of Water Rights, the State Water Resources Control Board issues permits to divert water for new appropriations or to change existing appropriative water rights.

The Proposed Action would not involve water obtained through riparian rights and would not impair any existing or known riparian rights to water in the San Joaquin River, Fresno River, or other rivers and streams.

The Proposed Action would enable banking of water for MID, a holder of both CVP contract entitlements and appropriative water rights. No water right amendments or applications are necessitated by the Proposed Action. Persons or entities that participate in and make use of the Proposed Action would not affect other appropriative water rights.

4.4.16 Madera County General Plan

The Madera County General Plan Policy Document (Madera County 1995b) contains agricultural water supply policies (General Plan 3.C.12) that state that the County would work with local irrigation districts to preserve local water rights. The County and MID oppose public and private sales of water rights to users outside Madera County. Specifically, the County's goal is to protect and enhance the natural qualities of streams, creeks, and groundwater (Goal 5.C). The general plan specifically states that the County shall protect and preserve areas with prime percolation capabilities (Goal 5.C.1).

4.4.17 Madera Irrigation District AB3030f Groundwater Management Plan

MID approved its AB3030 Groundwater Management Plan in May 1999. Some of the primary goals of the plan include:

- ensuring long-term availability of high-quality groundwater,
- maintaining local control of groundwater resources within MID, and
- prohibiting the net export of groundwater from MID and use of groundwater to replace surface water removed from MID as a result of a transfer.

The Proposed Action conforms to the mission statement and meets the primary goals listed above. The Proposed Action would ensure the long-term availability of high-quality groundwater, would maintain local control, and would avoid the net export of groundwater or surface water.

4.4.18 Madera County Integrated Regional Water Management Plan

The Integrated Regional Water Management Plan (Madera County 2008) contains detailed recommendations for long-term water quality protection and water supply planning in Madera County.

Section 5 Preparers and Reviewers

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RECLAMATION
Managing Water in the West

RECORD OF DECISION

Madera Irrigation District Water Supply Enhancement Project

ROD 06-127

Recommended by: Michael P. Jackson Date: 7/19/2011
Michael P. Jackson
Area Manager
South-Central California Area Office

Concurred by: Date: 7/25/2011
Russell W. Grimes
Acting Regional Environmental Officer
Mid-Pacific Regional Office

Approved by: Date: 8/1/2011
Donald R. Glaser
Regional Director
Mid-Pacific Regional Office

U.S. Department of the Interior
Bureau of Reclamation
Mid Pacific Region
South Central California Area Office
Fresno, California

July 2011

Introduction

Madera Irrigation District (MID) approved a Water Supply Enhancement Project (WSEP) located on the property known as Madera Ranch, west of the city of Madera, in Madera County, California in September 2005. MID adopted a Notice of Determination based on the Madera Irrigation District Water Supply Enhancement Project Final Environmental Impact Report (EIR) in compliance with the California Environmental Quality Act.

In 2006, MID approached The U.S. Department of the Interior, Bureau of Reclamation (Reclamation) to request the use of Central Valley Project (CVP) contract water outside of MID's current service area, modification of CVP facilities and federal funding for the WSEP. MID has been working toward securing federal funds to assist in the cost of purchasing Madera Ranch, as well as certain pre-construction, and construction activities associated with the WSEP.

In March 2009, the "Omnibus Public Land Management Act of 2009" (Public Law 111-11; H.R. 146-308) became law. Section 9102 of P.L. 111-11 includes authorization for the Secretary of the Interior to enter into a cooperative agreement through Reclamation with MID for the support of the final design and construction of the WSEP. Among other things, the cooperative agreement will address costs associated with the planning, design, permitting, and construction of the WSEP. Section 9102 limits the federal cost share to 25% of the total cost of the project or $22.5 million, whichever is less. Though federal funding is authorized none has yet to be appropriated.

Reclamation, as lead federal agency, prepared an Environmental Impact Statement (EIS 06-127) to analyze the impacts of approving the banking of MID CVP water outside MID's service area in the proposed WSEP, the modification of Reclamation's 24.2 Canal, and any potential federal funding to assist in the cost of the project. The U.S. Army Corps of Engineers (USACE) and the U.S. Fish and Wildlife Service (USFWS) were cooperating agencies during preparation of the EIS.

The Draft EIS was made available for public review for 60 days ending September 25, 2009, during which time Reclamation held a public meeting. Reclamation prepared responses to comments received during the public review and those responses were included in the Final EIS noticed in the Federal Register on June 8, 2011.

This Record of Decision (ROD) documents Reclamation's decision to approve Reduced Alternative B which includes the banking of MID CVP water outside MID's service area in the proposed WSEP, modification of Reclamation's 24.2 canal and potential federal funding. This ROD was prepared in accordance with the National Environmental Policy Act [NEPA] (42 USC 4321 et seq.) and the Council on Environmental Quality's NEPA implementing regulations (40 CFR 1500-1508). The decision made herein is based on the information and analysis contained within the Final EIS for the *Madera Irrigation District Water Supply Enhancement Project*. Reclamation has considered all comments received on the Proposed Action in developing this ROD.

Background

Currently, farmers in MID's service area use a combination of groundwater and surface water. During dry years there is not adequate surface water to meet the water demand and groundwater pumping increases substantially. The amount of groundwater pumped from the aquifer in the vicinity of Madera Ranch exceeds the amount of water recharged to the aquifer, resulting in groundwater overdraft. Even in wet years, the groundwater basin is in severe overdraft because groundwater pumping is steadily increasing for agricultural, municipal, and industrial use. This overdraft has caused the water table to decline resulting in degraded water quality and excess space in the aquifer that could be used to bank surface water.

The purpose of the proposed project is to:

- enhance water supply reliability and flexibility by using the excess aquifer space for surface water storage (water banking);
- reduce existing and future aquifer overdraft;
- reduce groundwater pumping costs;
- increase groundwater quality;
- encourage conjunctive use in the region as a means toward regional self-sufficiency.

The purpose of the proposed Federal action is to analyze the impacts of banking MID CVP water outside MID's service area, modifying of Reclamation's 24.2 Canal and potentially providing federal funding to assist in the cost of the project.

Decision

Reduced Alternative B, identified in Section 1.2 of the Final EIS as the Preferred Alternative, has been chosen as the best overall alternative as it meets a portion of MID's current and future water storage needs; utilizes space underground for surface water storage; reduces aquifer overdraft; encourages conjunctive use as a means toward regional self-sufficiency; and is the environmentally preferable alternative.

Reduced Alternative B directs recharge activities in fewer swales than Alternative B on a priority basis to help avoid effects to vernal pools , and limits the number of recharge basins to the minimum needed to meet the purpose of the action. Reduced Alternative B also incorporates other best management practices and mitigation measures as described in Section 2.7 of the Final EIS. These measures are required to implement the preferred alternative.

Reduced Alternative B will complete the water bank in two phases. Phase 1 will involve constructing necessary delivery infrastructure improvements, selectively using 550 acres of natural swales for recharge, and installing approximately five soil berms to direct recharge flows. Phase 2 will involve constructing 323 acres of recharge basins and facilities for recovery of banked water. Reclamation would approve banking of CVP water outside the MID service area and alteration of Reclamation's 24.2 canal.

Alternatives Considered in the Final EIS

Four Action Alternatives and a No Action Alternative were considered in the Final EIS. Each alternative other than the No Action Alternative met the purpose and need of the action however they varied in design features, cost and potential environmental impacts. The following is a brief description of project alternatives; specific details were published in the Final EIS.

Alternative A

For Alternative A, the No Action Alternative, MID would not bank MID CVP water (MID Long-Term Water Service Contract supplies from both the Friant Division and Hidden Unit) on Madera Ranch and Reclamation's delivery canals would not be altered. MID could bank non-CVP water on the property, and other limited on-site water banking and recovery facilities may be constructed if MID is able to find participants and funding to support these efforts.

MID estimates they would be able to apply less than 5,000 acre-feet (AF) per year of their own non-CVP water. Recovery operations likewise would be limited if Reclamation-owned facilities were not altered. This Alternative would not satisfy the purpose and need, and groundwater overdraft would continue in Madera County.

Alternative B

For Alternative B, Reclamation would approve a total banking capacity of 250,000 AF of MID CVP water outside the MID service area and the issuance of an MP-620 permit (a Reclamation Mid-Pacific Region permit issued for additions or alterations to Reclamation facilities) for modification to Reclamation's 24.2 canal and potential federal funding. After modification of the 24.2 canal and certain MID facilities, MID would be able to recharge and recover a maximum of 55,000 AF annually.

Alternative B will complete the water bank in two phases. Phase 1 will involve constructing necessary delivery infrastructure improvements using 700 acres of select natural swales for recharge, and will install approximately five soil berms to direct recharge flows. Phase 2 will involve constructing 1000 acres of recharge basins and facilities for recovery of banked water.

Alternative B met the purpose and need of the action, however, this Alternative could result in adverse effects to upland species and wetlands and as such resulted in the development of Reduced Alternative B.

Reduced Alternative B

Reduced Alternative B has a smaller footprint than Alternative B. As with Alternative B, this alternative will complete the water bank in two phases. Phase 1 will involve constructing necessary delivery infrastructure improvements using select natural swales for recharge (550 acres versus 700 acres as proposed under Alternative B), and will install approximately five soil berms to direct recharge flows. As with Alternative B, Reduced Alternative B will require issuance of a MP-620 permit for modification to Reclamation's 24.2 canal. Phase 2 will involve constructing a limited number of recharge basins (323 acres versus up to 1,000 acres under

Alternative B) and facilities for recovery of banked water. Reclamation will approve banking of CVP water outside the MID service area, alteration of the canal and potential federal funding.

Alternative C

Alternative C is a variation of Reduced Alternative B that would replace natural swale recharge solely with recharge basins. Phase 1 would involve recharge-related facilities only. Phase 2 would involve facilities for recovery of banked water. Reclamation would approve banking of CVP water outside the MID service area and alteration of Reclamation-owned facilities and potential federal funding.

This Alternative was considered financially infeasible for MID due to the construction costs for 1,000 acres of recharge basins during Phase 1.

Alternative D

For Alternative D, MID would enter into an agreement with Gravelly Ford Water District (GFWD) to improve the Gravelly Ford (GF) Canal to allow water to be conveyed from the San Joaquin River through the GF Canal. The water would be banked at Madera Ranch for later recovery and delivery through the canal back to the San Joaquin River. The existing GFWD pumping plant would be enlarged; the existing, associated pipeline replaced with a larger-diameter line; the GF Canal re-graded to a flat-bottom configuration to allow two-way flow; a new connection to the river constructed to allow recovery water to reach the river without flowing through the pumps; and appropriate gate structures constructed. On-site improvements allowing water banking and extraction, including a pumping plant and pipeline to allow distribution of water uphill from the GF Canal, would be constructed.

Phase 1 would involve recharge-related facilities only. Phase 2 would involve supplemental recharge facilities and facilities for recovery of banked water. Reclamation would approve banking of CVP water outside the MID service area and potential federal funding but no alteration of Reclamation-owned facilities would occur.

Alternative D was eliminated from consideration because it would require that the bank operate solely through water exchanges along the San Joaquin River which would have made MID dependent on other agencies to receive water. In addition, this Alternative would rely on San Joaquin River restoration operations that have not yet been finalized and that may not occur within the desired implementation time frame.

Basis of Decision, Issues Evaluated, and Factors Considered

Reclamation evaluated the potential direct, indirect and cumulative effects of the proposed alternatives. Resources evaluated include: aesthetics, agriculture, air quality, biological resources, cultural resources, environmental justice, geology, soils, seismicity and erosion, global climate change, growth inducing effects, hazards, public health and safety, land use, noise, public services and utilities, socioeconomics, traffic and circulation, water resources, water supply and wetlands.

In addition, Reclamation's evaluation determined that none of the alternatives would affect Indian Trust Assets (ITA) as the nearest ITA to the WSEP is the Table Mountain Rancheria which is located approximately 28 miles east-northeast of the Action area. No tribes possess legal property interests held in trust by the United States in the area affected by any of the alternatives.

Public and public agency comments were considered by Reclamation and addressed in the Final EIS. Concerns included potential impacts on water quality, water supply, water rights issues, impacts on biological resources, determination of the least environmentally damaging practicable alternative (LEDPA), Fish and Wildlife Coordination Act compliance, impacts to wetlands, mitigation and monitoring, habitat loss, and socioeconomic concerns related to economic impacts on farmers.

Environmentally Preferable Alternative

The President's Council on Environmental Quality Regulations Section 1505.2(b) states that where an EIS has been prepared, the Record of Decision shall "Identify all alternatives considered by the agency in reaching its decision, specifying the alternative or alternatives which were considered to be environmentally preferable".

Given the elimination of the Section 8 Canal Southwest Extension, reduction in the total number of swales used to minimize effects to wetlands, and identification of fewer basins to be constructed, Reclamation considers Reduced Alternative B the environmentally preferable alternative. In addition, it will have less adverse effects on both water quality and water supply in Madera Ranch and the surrounding area than Alternative A, the No Action Alternative; has less adverse effects to upland species and wetlands than Alternative B; is more financially feasible than Alternative C; and would not have to rely on San Joaquin River restoration operations as anticipated in Alternative D.

Implementing the Decision and Environmental Commitments

Reclamation will serve as project lead for the implementation of laws to protect water quality, natural resources and cultural resources including but not limited to the:

- National Environmental Policy Act;
- Clean Water Act;
- Clean Air Act;
- Endangered Species Act;
- National Historic Preservation Act;

- Archaeological Resources Protection Act;
- Native American Graves Protection and Repatriation Act.

Environmental Commitments

The following table describes the environmental commitments developed through a cooperative process involving Reclamation, USACE, USFWS, CDFG and MID. Each commitment will be implemented in accordance with the policies, guidance, and authorities of the agency having jurisdiction. Additional details on the environmental commitments are included in the Final EIS. The Final EIS also includes the Madera Ranch Mitigation, Grazing and Management Plan and the Monitoring and Operational Constraint Plan as appendices.

It should be noted that one of the planned locations (Section 5) for vernal pool creation discussed in the Final EIS is no longer suitable due to the July 2011 observation of blunt nosed leopard lizards (fully protected under the California Fish and Game Code). Additional environmental analysis and documentation would be required if the vernal pools are located outside of the area previously analyzed for potential impacts.

Identifier	Environmental Commitment	Commitment Specifications
Agriculture		
AG-1	Permanently Preserve Farmland by Establishing a Conservation Easement on Agricultural Land	MID will establish conservation easements on agricultural land at an effect-to-mitigation ratio of 2:1 to prevent permanent conversion of the land to urban uses and to increase farm viability. This mitigation will be in kind and used to mitigate the loss of farmland classified as prime farmland or farmland of statewide importance.
Air Quality		
AQ-1	Implement San Joaquin Valley Air Pollution Control District Regulation VIII Control Measures for construction emissions of PM10.	• All disturbed areas, including storage piles, that are not being actively used for construction purposes will be effectively stabilized against dust emissions using water, chemical stabilizer/suppressant, or vegetative ground cover. Chemical stabilizer/suppressants will not be used near waters of the United States. • All on-site unpaved roads and off-site unpaved access roads used during construction will be effectively stabilized against dust emissions using water or chemical stabilizer/suppressant. • All land-clearing, grubbing, scraping, excavating, land-leveling, grading, cut-and-fill, and demolition activities will be effectively controlled against fugitive dust emissions by applying water or presoaking. • All operations will limit or expeditiously remove the accumulation of mud or dirt from adjacent public streets at least once every 24 hours during operations (The use of dry rotary brushes is expressly prohibited except where preceded or accompanied by sufficient wetting to limit visible dust emissions. The use of blower devices is expressly forbidden.). After materials are added to or removed from the surface of outdoor storage piles, the piles will be effectively stabilized against fugitive dust emissions using sufficient water or chemical stabilizer/suppressant.
AQ-2	Reduce Emissions Associated with Idling Equipment	Per California Air Resources Board regulations (Title 13 of the California Code of Regulations, Sections 2480 and 2485), which limit idling of diesel-fueled commercial motor vehicles, MID will require that all diesel engines be shut off when not in use to reduce emissions from idling.
AQ-3	Use Electric Pumps	MID will use as many electric pumps as possible for recovery operations to reduce emissions associated with propane. If propane pumps are needed, MID will use engines with catalytic controls and that meet SJVAPCD best available control technology (BACT) requirement for engines over 50 hp.
Biological Resources		
BIO-1	Establish a Grasslands Conservation Easement	Mitigation for the loss of California annual grassland, alkali grassland, or Great Valley iodine brush scrub would consist of establishing a grasslands conservation easement at Madera Ranch over an area of habitat larger than the area subject to long-term degradation (2 acres conserved: 1 acre affected for swales) or permanent loss (3 acre conserved: 1 acre lost). MID also would implement a Madera Ranch Mitigation, Grazing, and Management Plan to improve existing on-site habitat through grazing management and species monitoring. This measure would compensate completely for the loss of these habitats.
BIO-2a	Preconstruction Surveys/Avoid Effects on Vernal Pools and Alkali Rain Pools	MID will minimize effects on species in this habitat by avoiding these wetlands to the extent practical. A buffer area will be established around suitable habitat for listed crustaceans in the action area, i.e., vernal pools. Buffer areas will be demarcated by installing fencing 250 feet from each occupied pool. A qualified biologist will flag the pools to be fenced, and temporary fences will be installed as the first order of work. Construction barrier fencing will be placed at the edge of the buffer areas. Temporary fences will be furnished, constructed, maintained, and later removed as shown on the construction plans, as specified in the special provisions, and as directed by the project engineer. Temporary fencing will be four feet high, orange, commercial-quality woven polypropylene. No construction activities will be permitted within the buffer zone (including staging or sidecasting of material) other than those activities necessary to erect the fencing. Erosion control measures will be employed adjacent to occupied listed crustacean habitat to prevent soil from eroding or falling into these areas. Natural/ biodegradable erosion control measures (e.g., straw wattles, hay bales) will be used. Plastic monofilament netting (erosion control matting) will not be allowed.
BIO-2b	Create, Restore, and/or Preserve Vernal Pools	MID will create, restore and/or preserve vernal pool habitat at Madera Ranch in an area protected under a conservation easement. Five acres of vernal habitat would be restored and/or preserved for each acre of vernal pool or alkali rain pool habitat lost as a result of activities associated with the Proposed Action (5 acre created: 1 acre lost). MID anticipates that the approximate split of these acreages will be 3:1 preservation and 2:1 creation/restoration. This ultimately will be determined based on wetland locations, soil conditions, and consultation with the Corps; soils, hydrology, vegetation, and species will be monitored. The performance standard for created vernal pools is to ensure the new vernal pools emulate the natural pools at Madera Ranch. Created vernal pools would have similar plant species composition and vegetation cover and invertebrate fauna as the vernal pools that are being removed by activities associated with the Proposed Action. Success of the vernal pool creation would be assessed by comparing the pools with undisturbed natural vernal pools at Madera Ranch. Restored vernal pools will have similar success criteria. This mitigation would compensate for the loss of vernal pool habitat. Restoration is more likely to be successful in areas with degraded habitat and where preservation is the most assured. In addition, MID will comply with Reclamation's wetlands mitigation and enhancement policy, which focuses on protecting, restoring, and enhancing wetlands and ensuring no overall net loss of wetlands. Wetland mitigation creation and restoration sites will be monitored until it is proven successful to the Corps, USFWS, and DFG. Mitigation sites must function for at least three years without human intervention.
BIO-3a	Avoid Effects on Iodine Bush Scrub	MID will locate the well and pipeline to avoid direct effects on iodine bush scrub habitat in the northern portion of Section 7 associated with construction activities. If wells and pipelines need to be constructed in this habitat, MID will conduct botanical surveys and mark plants to be avoided during construction.
BIO-3b	Survey for Sensitive Plants	During Phase 1, two botanists conducted visual surveys for palmate-bracted bird's beak (*Cordylanthus palmatus*) and other sensitive plant species along a 60-foot corridor (30 feet per side) along the proposed pipeline and canal alignments and in the swales east of Gravelly Ford Canal. The surveys were conducted in April and July and reference populations were visited. No listed species were found and sensitive *Atriplex* species were mapped to minimize future effects. The results of the botanical surveys will be used to determine which avoidance, minimization, and environmental commitments will be employed. During Phase 2, additional botanical surveys will be conducted in the area proposed for recharge basin creation. Complete visual surveys will be conducted in a similar manner in all areas proposed for permanent ground disturbance. If palmate-bracted bird's beak is found, the population will be delineated with highly visible flagging tape or plastic fencing and avoided. If other sensitive species are found, MID, DFG and USFWS will coordinate to determine the feasibility of avoiding the population.
BIO-4a	Preconstruction Surveys for California Tiger Salamander	A USFWS-approved biologist will conduct preconstruction surveys for California tiger salamander (*Ambystoma californiense [=A. tigrinum c.]*) in suitable aquatic and upland habitat. Before the start of ground-disturbing activities or vegetation removal, the approved biologist or biological monitor will survey the area to be affected that day for California tiger salamanders. The biologist also will examine any open trenches, which will have ramps or be closed when unattended, for the presence of salamanders. If a salamander is found in the construction area, the approved biologist will remove the animal from the area and release it into a suitable burrow at least 300 feet outside the construction area. The biologist will document the results of surveys on preconstruction survey log sheets, which will be kept on file at MID.
BIO-4b	Restrict Construction Activity in Suitable Aquatic and Upland Habitat for California Tiger Salamander to the Dry Season (April 1–November 1)	To avoid and minimize potential mortality and injury of breeding and dispersing California tiger salamanders, construction will take place only during the dry season (between April 1 and November 1 or before the onset of the rainy season, whichever occurs first) in suitable aquatic and upland habitat for the species. Upland habitat is defined as all habitat within one mile of occupied or suitable aquatic habitat. Specifically, this measure applies to all pipeline construction on Madera Ranch and during work at all delivery canals. This measure does not apply to construction activities in gravel shoulders and heavily disturbed non-habitat areas where construction is confined entirely to areas devoid of upland grassland habitat.
BIO-4c	Fence the Construction Zone and Implement Erosion Control Measures in Areas Where Suitable Aquatic Habitat for California Tiger Salamander Is Present	The construction zone will be fenced in areas where suitable aquatic habitat for California tiger salamander is adjacent to the construction area. The purpose of the fence is to restrict construction equipment to the designated area only. Erosion control measures also will be implemented in these areas to prevent any soil or other materials from entering aquatic habitat. Locations of temporary fences and erosion control measures will be shown on the construction plans and will be reviewed by a qualified biologist. Construction barrier fencing will be installed along the edge of the work area as the first order of work. Temporary fences will be furnished, constructed, maintained, and later removed as shown on the plans, as specified in the special provisions, and as directed by the project engineer. No construction activities will be permitted outside the designated construction zone other than those activities necessary to erect the fencing. Erosion control measures will be installed

Identifier	Environmental Commitment	Commitment Specifications
		adjacent to suitable aquatic habitat to prevent soil from eroding or falling into these areas. Natural/biodegradable erosion control measures (e.g., straw wattles, hay bales) will be used. Plastic monofilament netting (erosion control matting) will not be allowed because salamanders can be caught in this type of material.
BIO-5	Pre-Activity Surveys for Blunt-Nosed Leopard Lizard	The objective of the blunt-nosed leopard lizard (*Gambelia [=Crotaphytus] sila*) (blunt-nosed leopard lizard) surveys is to avoid take of blunt-nosed leopard lizard during use of the swales for water banking and construction of water delivery canals and other facilities. Specific measures for linear facilities and swales are described below.
Bio-5a	Install exclusion fencing and conduct clearance surveys and construction monitoring for blunt-nosed leopard lizards	Prior to construction of linear facilities in grassland and/or saltbush scrub/Valley sink scrub habitat and adjacent dirt roadways MID, in consultation and coordination with qualified wildlife biologists, shall create exclusion corridors based on habitat suitability and the need to create exclusion zones for burrows, scalds, and wetlands. Construction of linear facilities is restricted to May 1st through August 1st and may commence in areas only after Blunt-Nosed Leopard Lizard ("BNLL") pre-construction surveys are completed. Pre-activity BNLL surveys were coordinated with the USFWS and CDFG since California's Fish and Game Code does not allow take of this species. Pre-activity surveys shall consist of the following minimum parameters: • Surveys for adult BNLL shall be conducted between April 28th and July 1st and shall occur when the air temperature (as measured at 1-2 cm above the ground over a surface most representative of the area being surveyed) is between 25 °C - 35 °C (77 °F – 95 °F). Once the air temperature falls within the optimal range, surveys may begin after sunrise (once sun is high enough to shine directly on the ground surface being surveyed) and must end by 1400 hours or when the maximum air temperature is reached, whichever occurs first. • Time of day and air temperature shall be recorded at the start and end of each survey. • Surveys will not be conducted on overcast (cloud cover > 90%) or rainy days or when sustained wind velocity exceeds 10 mph (>3 on Beaufort wind scale). • Surveys shall be conducted on foot and transects shall be no larger than 10 meters wide, consist of a slow pace, and be conducted on a north-south orientation when possible. • Surveys shall be conducted for 12 days over the course of a 30 day period. Surveys shall be conducted for 4 consecutive days, weather permitting with at least one survey session consisting of a 4 consecutive day period. • The starting/ending locations of surveys should be modified/alternated to the extent practicable, but resulting in the same area surveyed. This is so that different portions of the site are surveyed at different time/temp periods. • Surveyors must be approved by the DFG and USFWS to conduct the BNLL reconnaissance surveys. The survey crew conducting focused BNLL surveys shall consist of no more than 3 Level I surveyors for every Level II surveyor. The names of every surveyor must be recorded for each survey day. • All herpetofauna observations shall be recorded/tallied. All BNLL observations shall be recorded with GPS, time of observation, name of observer, sex (if evident), and lifestage (adult, juvenile, hatchling). If BNLL is observed in association with or observed entering a particular burrow, burrow location (via GPS) should be recorded as well. • If a BNLL is observed within such areas, consultation with CDFG must immediately occur. However, if BNLL observations are made, BNLL surveys should not be halted; the entire survey should be completed for the entirety of the construction footprint; continuing the surveys is important to maximize detections and to best help inform where the lizards occur and may not occur. Partial surveys cannot be used to inform whether or not avoidance can or will occur. • (hereafter 1- 9 collectively referred to as, "BNLL Pre-Construction Survey Parameters".) Installation of Barrier - Within 3 days after BNLL pre-construction surveys are completed, biologists shall oversee the creation an exclusion area by installing a non-gaping non-climbable barrier using a material approved by DFG and the USFWS along 3 sides of the planned linear facility construction perimeter. The barrier installation shall be overseen by biologists who have BNLL experience and who have been approved in advance by USFWS and DFG (hereafter, qualified BNLL biologists). The barrier fencing shall be installed perpendicular to the ground (vertical) and shall be sealed to ensure there are no gaps between segments or under the fencing. An example of possible suitable material can be found at http://www.ertecsystems.com/. Small mammal burrows and burrow complexes shall be excluded from the liner facility construction areas to the maximum extent practicable and a no disturbance buffer zone shall be established and clearly delineated from any burrows / burrow complexes. The day following the installation of the fencing, the qualified BNLL biologists shall walk approximately 10 meter transects along the partially fenced linear facility construction area during the time of day when air temperatures fall within the optimum range for species detection, during the peak BNLL activity season, and as outlined above. If no BNLL are detected, the fourth side of fencing may be installed and MID may begin work within the fenced area. At least two DFG and USFWS approved biologists will be present within the construction area when construction and other activities within the exclusion area are in progress. Walking Surveys Throughout Construction - Throughout construction, the biologists shall conduct walking surveys of the construction area, looking for BNLL. All open holes and trenches within habitat will be inspected at the beginning of the day, middle of the day, and end of day for trapped animals. If BNLL are detected at any time and within any area of the basin construction site, biologists will halt all work, open a section of the exclusion fencing, and allow the lizard to leave the area on its own (no chasing, following, etc. can occur). Inadvertent Entrapment Prevention-- To prevent inadvertent entrapment of BNLL or any other wildlife during the construction phase of the linear facilities, all excavated, steep-walled holes or trenches more than 2 feet deep shall be covered at the close of each working day by plywood or similar materials or provided with one or more escape ramps (with no greater than a 3:1 slope) constructed of earth fill or wooden planks. Before such holes or trenches are filled, they shall be thoroughly inspected for trapped animals by a qualified biologist. If BNLL are trapped, then it shall be allowed to escape on its own. In addition, all construction pipe, culverts, or similar structures with a diameter of 7.6 centimeters (3 inches) or greater that are stored at the construction site for one or more overnight periods will be thoroughly inspected for BNLL before the pipe is subsequently moved, buried, or capped. If during inspection one of these animals is discovered inside a pipe that section of pipe shall not be moved until the animal has escaped on its own. Construction Time - The permitted construction time is from one hour after sunrise to one hour before sunset, and two biological monitors shall also be active at all times when construction or other activities are in progress. The biological monitors shall survey the construction area during construction, scanning the ground for BNLL and routinely checking excavated soils to ensure that BNLL are not present. The biological monitors shall stop work if a lizard is found within the construction area until the lizard has been excluded from the work area. Multiple Construction Areas More than one linear facility construction area may be established and under construction at the same time provided the minimum number of biologists and biological monitors are present at each of the sites at all times during construction or other related activities. Notification of Dead or Injured BNLL - If any dead or injured BNLL are observed on or adjacent to the construction site, or along haul roads/travel routes for worker and/or equipment, regardless of assumed cause, DFG and USFWS shall be notified. The initial notification to DFG and USFWS shall include information regarding the location, species, and the number of animals injured or killed. Following initial notification, MID shall send DFG and USFWS a written report within 2 calendar days. The report shall include the date and time of the finding or incident, location of the carcass, and if possible provide a photograph, explanation as to cause of death, and any other pertinent information. Fully Protected Species - These measures shall not be required if the species' fully protected status is rescinded and MID obtains incidental take authorization from DFG for this species for this project.

Identifier	Environmental Commitment	Commitment Specifications
		Recharge Basins MID, in consultation and coordination with qualified wildlife biologists, shall create appropriately sized recharge basin construction areas before construction of recharge basins in grassland and/or saltbush scrub/Valley sink scrub habitat and adjacent dirt roadways within the former center pivot areas of Section 16, 17, and 18 on Madera Ranch. Construction areas shall be prioritized initially by reconnaissance surveys no more than 60 days prior to any basin construction activities or ground disturbance to identify areas with the fewest burrows and least suitable habitat for BNLL. Construction of basins will be restricted to May 1st through August 1st and may commence in areas identified through the above referenced reconnaissance surveys only after BNLL pre-construction surveys are completed by way of the BNLL Pre-Construction Survey Parameters (See paragraph I.A. above). The information gathered from these surveys will be used by DFG to determine which habitat is most likely occupied and to identify appropriate exclusion areas. (Basins shall initially be planned to be sited in the former center pivot areas of Section 16, 17, and 18.) If no BNLL is observed within 3 days after the completion of the BNLL pre-construction survey, biologists shall create an exclusion area by installing non-gaping non-climbable barrier. The installation for such barrier shall comply with the installation guidelines listed above under linear facilities, and must be supervised by a qualified BNLL biologist. (See paragraph I.B above.) Construction of the recharge basins is permitted from one hour after sunrise to one hour before sunset. (See I.E above.) More than one percolation basin construction area may be establish and under construction at the same time provided the minimum number of biologists and biological monitors are present at each of the sites at all times during construction or other related activities. Throughout construction, Biologists shall conduct walking surveys of the construction area to determine whether there is any detection of the BNLL. The survey procedures shall comply with paragraph I.C. listed above. Also during construction, all excavated, steep-walled holes or trenches more than 2 feet deep shall be covered as described under I.D above, to prevent inadvertent entrapment of BNLL or any other wildlife. Finally, if any dead or injured BNLL are observed on or adjacent to the construction site, then MID must notified DFG and USFWS in accordance with the outline procedures listed above under I.G. If the BNLL fully protected status is rescinded and an incidental take permit is granted, then these measures will not be required. *On-Ranch Ground Disturbing Facility Maintenance* MID will have an agency approved biologist review future ground disturbing facility maintenance work locations and sizes to evaluate the potential for effects to BNLL. If the activity is in suitable habitat and could affect burrows, MID will conduct the work during the appropriate seasonal window and implement site-specific exclusion measures such as fencing and additional surveys as prescribed above for linear facilities.
Bio-5b	Conduct blunt-nosed leopard lizard and burrow surveys of swales proposed for inundation	MID will conduct BNLL and burrow surveys of swales prior to inundation in swales. Those portions of swales that have been inundated annually for extended periods prior to Project approval will not be surveyed because potential burrows likely have been inundated and eroded, and BNLL are unlikely to aestivate in these areas. Pre-wetting BNLL surveys will be consistent with the *BNLL Pre-Construction Survey Parameters* listed above under I.A.. The information from these surveys will be used to determine which habitat is most likely occupied and to identify appropriate swale use areas. If no BNLL are found during the surveys, water may be applied throughout that following year. If a BNLL is sighted within the low point of a swale (i.e., the expected inundation area) it will be difficult to determine whether the burrows in the area are being used for nesting or refugia. Therefore, MID will delay using the swale for banking until the active season (April 28 to July 1); then MID will apply water to the swale slowly (i.e., approximately 12 inches per minute) to ensure lizards can escape burrows. These measures shall not be required if the species' fully protected status is rescinded and MID obtains incidental take authorization from DFG for this species for this project.
Bio-5c	Implement other protective measures for blunt-nosed leopard lizard	MID will implement other protective measures for blunt-nosed leopard lizard. MID would create at least three canal crossings along Gravelly Ford Canal and 6 canal crossings along the Section 8 Canal Northern Extension; the width of the crossings will vary from approximately 16 feet along Gravelly Ford Canal to approximately eight feet along the Section 8 Canal Northern Extension. While making Gravelly Ford Canal improvements and installing the Section 8 Canal Northern Extension, MID would excavate slightly below the bottom grade of the canal to install a culvert and provide for a crossing to connect the habitat units. The area would be backfilled, covering the crossing with soil from the canal improvement. A similar concept would be employed for the Section 8 Canal Northern Extension, though the length of the pipe segment would be four to eight feet and because of the flat hydraulic grade one larger pipe may be used. Additionally, on-ranch canal side slopes will be designed to allow BNLL to avoid entrapment.
BIO-6	Preconstruction Surveys and Avoidance Activities for Raptors	Preconstruction surveys would determine whether any sensitive raptors are nesting at Madera Ranch. If a tree is occupied at the time of construction, construction activities will be restricted to areas outside 0.5 mile of the tree. Setbacks will be marked with brightly colored temporary fencing.
BIO-7	Preconstruction Surveys for Western Burrowing Owl	The initial daytime burrow survey will help inform the Western burrowing owl (*Athene cunicularia*) survey. A qualified wildlife biologist will conduct a burrowing owl survey in accordance with DFG guidelines. The survey area will include the construction corridor and a 500-foot buffer. An initial survey will determine whether burrowing owls are present. Three additional surveys will be conducted to determine presence or absence of burrowing owls. In accordance with DFG survey guidelines, these surveys must be conducted on four separate days—two in the early morning and two in the late afternoon/early evening. Non-nesting owls may be passively relocated, also using DFG's guidelines.
BIO-8	Preconstruction Surveys for San Joaquin Kit Fox	Because of historical records and suitable San Joaquin kit fox (*Vulpes macrotis mutica*) habitat on or in the vicinity of Madera Ranch, it is assumed that kit foxes could be present at Madera Ranch. To avoid potential mortality of kit fox, agency approved (by USFWS and DFG) experienced biologists will survey to locate any natal dens, non-natal active dens, and/or potential dens in the Proposed Action area. Visual surveys will be conducted during meandering transects of the 1,000 foot corridor. If an active natal den is found, USFWS and DFG will be notified and MID will delay construction within 1,000 feet of the den until the pups have been weaned or moved to an off-site den, and/or reroute the construction corridor to avoid impacts on the kit foxes. Standard Kit fox provisions will be followed in accordance with. U.S. Fish and Wildlife Service Standardized Recommendations for Protection of the Endangered San Joaquin Kit Fox Prior to or During Ground Disturbance. Surveying will include meandering transect surveys for active dens (non-natal) out to 250 feet from the proposed facilities, which will involve simultaneous surveys for potential den sites out to 100 feet. If an active den is found, it will be avoided until the foxes have vacated the den. All potential dens will be flagged. Any potential den immediately in the construction corridor may need additional monitoring. Because construction is expected to proceed quickly—approximately 1,000 feet per day with trenches being open one to two nights—potential dens will not be collapsed. All surveys will be conducted within 30 days of site-specific construction by a qualified biologist. In addition, during construction, USFWS standard kit fox conservation measures such as speed limits, exit ramps, controlling toxic (oil or gas) spills from construction equipment, and covering pipes will be implemented to prevent harm or disturbance to kit foxes using the area. Any open pipes, newly dug pipeline trenches, and canals will be surveyed daily prior to construction to ensure kit foxes are not present.
BIO 9	Conduct Pre-Activity Surveys for Fresno Kangaroo Rat	The objective of the Fresno kangaroo rat (*Dipodomys nitratoides exilis*) surveys is to determine whether the Fresno kangaroo rat is present on the portion of Madera Ranch that could be affected by use of the swales for water banking and construction of water delivery canals. Initial trapping focused on the swales and canals east of GF Canal and determined the species was not present. Subsequent trapping will occur 1-year before use of swales or construction of facilities west of GF Canal. Surveys in swales will be conducted 1 to 2 years before the first wetting of the swale and will be valid for 5 years after the wetting of the swale. If the swale is re-wetted within the 5-year period, it will not need to be surveyed for another 5-year period. No additional survey efforts will be conducted of any swale

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		areas that have been surveyed twice with neither survey resulting in a single trapping of the Fresno kangaroo rat. Kangaroo rat trapping efforts will be conducted by a surveyor holding a recovery permit for the Fresno kangaroo rat (10[a][1][A] permit). Meandering visual transect surveys for kangaroo rat burrow complexes and sign (e.g., tail drags, sand baths, seed caches) will be conducted by two to four biologists over all habitat within and out to 250 feet from the edge of the WSEP footprint, including swales, and within 100 feet of the top of GF Canal. All burrow complexes found will be recorded on a GPS unit, and data on the number of burrows, level of activity, and general suitability for kangaroo rats will be recorded in field notes (burrows suitable for kit fox also will be noted on GPS as part of this effort); information on vegetation type and percent cover also will be recorded. Following completion of the survey, potential trapping-sites will be prioritized based on a combination of the level of kangaroo rat activity (as evidenced by burrow density and/or the presence of other sign, though some areas without obvious sign may also be trapped) and project area coverage. Live trap stations and trap lines then will be established (staked and recorded with a GPS unit) by permitted biologists at the highest priority sites. Traps (Sherman live traps [Model XLKR: 13 inches x 3.5 inches x 3 inches]) will be set near active burrows, dust baths, or tracks, particularly along evident runways. Ten or more traps (or a number determined by the surveyor) will be set in relatively tight clusters (5-foot trap spacing) at high activity areas. Traps also will be set at 10 to 15 meter intervals (two traps per station) along evident movement corridors. Traps will be baited with a mixture of millet seed, crimped oats, wild birdseed, or other suitable seed. Bedding (crumpled unbleached paper towel) will be placed at the inside end of each trap and will not be allowed to contact the tripping mechanism. Paper towels will be replaced each time an animal is captured in the trap. Traps will be opened and baited at sunset and checked 1-2 times/evening as deemed appropriate by the lead biologist. All traps will be closed after they have been checked at dawn. Trapping will be conducted at each trap site for five consecutive nights. Trapping will not be conducted during the week of a full moon, unless the sky is overcast and moonlight is substantially reduced. Trapping will not be conducted in December or January or in periods of cold or inclement weather detrimental to kangaroo rats and as stipulated in the surveyor's recovery permit. Although Fresno kangaroo rats are active year round, their populations generally are lowest at this time. All non-Fresno kangaroo rats captured will be marked with a nontoxic semi-permanent ink marker on the belly to identify the re-trapping of the same animal(s). Trapping will cease with the capture of a Fresno kangaroo rat and MID, the USFWS, and DFG will be notified as soon as possible, if not the same day, then the next workday, or no later than the Monday following the capture should it occur on a Friday or Saturday night. Any measurements obtained to provide evidence that the animal captured is a Fresno kangaroo rat will be achieved with minimal and delicate handling fur and tissue samples will be taken only by a qualified, permitted biologist in accordance with their permit terms. A photo of the animal's hind legs (showing toes and including a ruler) will be taken and the animal will be immediately released; the animal's eyes will be shielded from the flash. The lead biologist will notify MID of the proposed trapping schedule and will inform MID weekly which trapping areas have been completed. Any capture of Fresno kangaroo rat will be reported immediately to MID, the USFWS, DFG, and Reclamation.
BIO-10	Conduct Preconstruction Surveys for Sensitive Species along the Off-Ranch Portion of Gravelly Ford Canal	Proposed off-ranch work areas associated with GF Canal improvements will be evaluated by a USFWS-approved biologist to determine whether habitat suitable to support sensitive species is present. If suitable habitat is discovered, MID will evaluate work locations to determine which species could be present and whether additional surveys may be needed. Depending on the results of this survey, MID also may implement Environmental Commitment BIO-1: Establish a Grasslands Conservation Easement, Environmental Commitment BIO-5: Pre-Activity Surveys for Blunt-Nosed Leopard Lizard, Environmental Commitment BIO-6: Preconstruction Surveys and Avoidance Activities for Raptors, and Environmental Commitment BIO-7: Preconstruction Surveys for Western Burrowing Owl.
BIO-11	Implement Protective Measures for Anadromous Fish	MID would work with Reclamation and the National Marine Fisheries Service (NMFS) to determine appropriate protective measures for migratory fish once they are restored to the San Joaquin River, including seasonal restrictions on diversions or intake screening in the event water is moved to and from Madera Ranch via GF Canal (Alternative D). Inter-agency discussions would occur at least two years in advance of the reintroduction of these species to the San Joaquin River.

Biological Opinion Commitments

On April 26, 2011, the USFWS issued a Biological Opinion to Reclamation (File Number 81420-2008-F-0279-1) to address the impacts of Reduced Alternative B on Federally listed species. The Biological Opinion was included in the Final EIS as Appendix B. The following additional commitments (terms and conditions) are also imposed on Reduced Alternative B from the incidental take statement that was provided with the Biological Opinion.

Reasonable and Prudent Measures		Terms and Conditions
The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize the effects of the proposed Madera Irrigation District Water Supply Enhancement Project on the San Joaquin kit fox, blunt-nosed leopard lizard, Fresno kangaroo rat, vernal pool fairy shrimp, vernal pool tadpole shrimp, Conservancy fairy shrimp, and California tiger salamander.		In order to be exempt from the prohibitions of section 9 of the Act, Reclamation must comply with the following terms and conditions, which implement the reasonable and prudent measures. These terms and conditions are non-discretionary.
1.	All Environmental Commitments as described in the Biological Assessment, and as restated here in the *Description of the Proposed Action* of this Biological Opinion, must be fully implemented and adhered to.	To implement Reasonable and Prudent Measure #1, Reclamation shall ensure through conditions in its approval letter or any funding for the proposed project that Madera Irrigation District fully implements and adheres to the Environmental Commitments presented in the Biological Assessment and restated here in this Biological Opinion. These Environmental Commitments must be adhered to, regardless of species status under the California Endangered Species Act.
2.	Land that is to be set aside as habitat compensation and managed for the primary purpose of benefitting those listed species impacted by the proposed project must be protected in perpetuity, and with the intent to provide optimum conditions for those species.	To implement Reasonable and Prudent Measure #2, Reclamation shall ensure through conditions in its approval letter for the proposed project the following Terms and Conditions: a) Reclamation shall ensure that Madera Irrigation District grants and records an appropriate, Service-approved Conservation Easement with a Service-approved Conservation Easement holder for the mitigation lands described in the Biological Assessment, prior to project implementation. b) Reclamation shall ensure that Madera Irrigation District incorporates by reference its Mitigation and Management Plan, developed for these mitigation lands, into said Conservation Easement. c) Reclamation shall ensure that Madera Irrigation District includes language in the Conservation Easement stating that the Mitigation and Management Plan created for this project is a living document, to be viewed and used as an adaptive management plan under the direction and approval of the Service, CDFG & Corps, with the goal of ensuring optimum habitat conditions for the species of concern. d) Reclamation shall ensure that Madera Irrigation District has in place prior to project implementation an adequate, Service-approved funding mechanism, such as a non-wasting endowment held by a Service-approved endowment holder to fund the long-term management activities on their mitigation lands.
3.	To ensure that the expected changes to ecological conditions resulting from swale inundation do not result in take of Fresno kangaroo rats and blunt-nosed leopard lizards beyond what is anticipated in this biological opinion, hydrological conditions must be maintained such that there is no more than a 20 percent increase in acreage of vegetative changes beyond the perimeter of water applications (footprint of swales and seasonal wetlands).	To implement Reasonable and Prudent Measure #3, Reclamation shall ensure through conditions in its approval letter or any funding instrument for the proposed project that MID develops and implements an appropriate Service-approved hydrological study or studies, designed to monitor and report on conditions related to changing ecosystem characteristics in and adjacent to the swales used for water banking purposes. Such studies, and the information obtained from them, shall be used to inform Reclamation and MID of the degree and nature of habitat modification from current conditions, and whether take resulting from vegetative changes beyond the perimeter of water applications (i.e., greater than 20 percent) is exceeded. The information gathered from these studies shall be provided to the Service and CDFG on thirty-day cycles or within thirty days of conclusion of a study cycle.
4.	The periodicity of swale inundation over the duration of this project must be monitored and adjusted, if necessary, to ensure that the time interval between swale flooding events does not result in a biological "sink" for Fresno kangaroo rats and blunt-nosed leopard lizards, whereby individuals of these species that may re-colonize burrows in or immediately adjacent to swales during dry periods are then taken by subsequent flooding. These adjustments could include repeated and/or more frequent wetting if the water supply is available, varying the priority/rotation of wetted swales, scaling back swale operations consistent with overall banking operational objectives, or other measures agreed to by MID, Reclamation, the Service, and CDFG.	To implement Reasonable and Prudent Measure #4, Reclamation shall ensure through conditions in its approval letter or any funding for the proposed project that Madera Irrigation District develop a Service-approved monitoring and reporting approach for the inundated swales and adjacent habitat sufficient to determine whether Fresno kangaroo rats and blunt-nosed leopard lizards re-colonize these areas during dry periods.

Identifier	Environmental Commitment	Commitment Specifications
Cultural Resources		
CR-1	Stop Construction If Cultural Resources Are Discovered	In the event of any inadvertent cultural resources discovery, human or otherwise, uncovered during construction or other ground-disturbing activities, the construction contractor will immediately stop work in the immediate vicinity and a minimum 100-foot buffer area from the find. The contractor will notify MID immediately and MID will notify Reclamation of the inadvertent discovery. A professionally qualified archaeologist will be sent to evaluate the inadvertent discovery for National Register of Historic Places (NRHP) eligibility. If human remains are discovered during ground-disturbing activities, the party responsible for CEQA will comply with state laws[1] relating to the disposition of human remains pursuant to Public Resources Code (PRC) section 5097. Reclamation may have additional responsibilities under Section 106 of the NHPA and will follow the procedures in 36 CFR Part 800.13.
Geology, Soils, Seismicity and Erosion		
GEO-1	Amend Soils as Required in Topsoiled Areas	Topsoiled areas with insufficient vegetation cover will be amended with gypsum and/or elemental sulfur in combination with high-quality irrigation water to reduce soil salinity, alkalinity, and exchangeable sodium to acceptable levels, such that acceptable vegetation cover is established in such areas within one year after topsoil is applied. All soil sampling and amendment recommendations will be conducted by, or under the supervision of, a certified professional soil scientist.
GEO-2	Stop Work in Event of Fossil Discovery	In the event that a fossil or material that could be a fossil is unexpectedly discovered during excavation operations, work will cease in the immediate vicinity of the find. A qualified paleontologist will be called to the site to evaluate the find and determine the sensitivity of the fossil. If the fossil is determined to be sensitive, the paleontologist will recover it from the site and submit it to an appropriate museum or other repository for curation.
Hazards, Public Health and Safety		
PHS-1a	Implement Necessary Emergency Preparedness Plan(s)	MID will work with the Madera County Department of Public Health and the local fire districts to coordinate the preparation of emergency preparedness plan(s) that may be required by federal, state, and County statutes and regulations.
PHS-1b	Comply with Local Fire District Requirements	MID will consult the local fire districts to ensure that all regulations are complied with during construction.
PHS-2	Implement an Agreement with the Madera County Mosquito and Vector Control District	MID will enter into an agreement with the Madera County Mosquito Abatement & Vector Control District (MCMAVCD) regarding a specific mosquito abatement program. The agreement will allow the MCMAVCD to access Madera Ranch and also will include quantitative abatement thresholds and financial compensation requirements for MCMAVCD activities, if necessary. The MCMAVCD will monitor mosquito larvae production in the recharge basins, drainages, and distribution canals at no cost to MID, given that the amount of monitoring required is not excessive. Larvae populations will be tracked using methods and thresholds approved by the MCMAVCD, and suppression measures will be employed when thresholds are exceeded. Suppression measures may include environmental and biological methods, such as stocking mosquitofish, controlling emergent vegetation, and applying insecticides. Insecticide controls will be used only as a last resort, and use of insecticides over open water will be minimized to the extent feasible, given the mosquito abatement mandate of the MCMAVCD. The insecticides that may be used are only those that are approved for such uses by the U.S. Environmental Protection Agency (EPA). Mosquitofish, if used, will need to be stocked annually by the MCMAVCD. If operations result in an increase in mosquito production such that an extensive monitoring program is needed, MID will hire a professional pest control service and will bear the cost of that service.
Noise		
NOI-1	The construction contractor will employ noise-reducing construction practices so that noise from construction does not exceed County noise-level standards at adjacent residences.	Measures to be implemented would include the following. • Restrict construction to beyond 3,900 feet from residences during nighttime hours (10 p.m. to 7 a.m.). • Provide construction equipment with sound-control devices no less effective than those provided on the original equipment. No equipment will have an unmuffled exhaust. • Implement appropriate additional noise environmental commitments, including (but not limited to) changing the location of stationary construction equipment, shutting off idling equipment, rescheduling construction activity, notifying adjacent residents in advance of construction work, and installing acoustic barriers around stationary construction noise sources.
NOI-2	The construction contractor will employ noise-reducing methods during well drilling operations	The drilling contractor will employ noise-reducing construction practices so that noise from drilling does not exceed County noise-level standards at adjacent residences. Measures to be implemented may include those following. • Restrict well drilling to beyond 2,900 feet from residences during nighttime hours (10 p.m. to 7 a.m.), where feasible. • Use sound attenuation enclosures around noise-generating elements of the drilling operation.
NOI-3	The construction contractor will employ noise-reducing practices so that noise from well operations does not exceed County noise-level standards at adjacent residences.	Measures to be implemented may include: • restricting well installations to beyond 1,250 feet from residences, where feasible; • using electric pumps where well installations are within 1,250 feet of residences; and • using sound attenuation enclosures designed to achieve noise reductions sufficient to comply with County standards for noise-generating elements of the well operation when no other feasible control method is available.
NOI-4	The construction contractor will employ noise-reducing practices so that noise from lift station operations does not exceed County noise-level standards at adjacent residences	Measures to be implemented may include: • restricting lift station installations to beyond 1,600 feet from residences, where feasible; • using electric pumps where lift station installations are within 1,600 feet of residences; or • using sound attenuation enclosures designed to achieve noise reductions sufficient to comply with County standards for noise-generating elements of the lift station operation when no other feasible control method is available.

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[1] Madera Ranch does not include federal land, so only state human-remains laws apply.

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Public Services		
PSU-1a	Notify Emergency-Response Agencies of Proposed Traffic-Route Changes	Before beginning construction activities, MID or the construction contractor will contact local emergency-response agencies (law enforcement and fire protection) to provide information on the timing and location of any traffic control measures required during construction activities. Emergency-response agencies will be notified of any change to traffic control measures as the construction phases proceed so that emergency-response providers can modify their response routes to ensure that response time would not be affected.
PSU-1b	MID will require the construction contractor to prepare and implement a traffic safety plan (TSP) before the onset of construction activities.	The TSP will address: • appropriate vehicle size and speed, • travel routes, • detour or lane-closure plans, • flag person requirements, • locations of turnouts to be constructed, • coordination with law enforcement and fire control agencies, • coordination with California Department of Transportation (Caltrans) personnel (for work affecting state road rights-of way), • emergency access to ensure public safety, and • traffic and speed-limit signs.
Traffic		
TRAF-1	MID will require the construction contractor to prepare and implement a road improvement plan (RIP) before the onset of the construction phase.	The RIP will identify road segments, bridges, and culverts that need to be improved and turnout locations that need to be constructed (as applicable) to accommodate construction activities. The plan also will identify damage that is caused by construction vehicles and that needs to be repaired.
Water Resources		
WQ-1a	Comply with National Pollutant Discharge Elimination System General Construction Permit	To reduce or eliminate construction-related water quality effects, before onset of any construction activities, MID or its contractor will obtain coverage under the National Pollutant Discharge Elimination System (NPDES) General Construction Permit. MID will be responsible to ensure that construction activities comply with the conditions in this permit, which will require development of a stormwater pollution prevention plan (SWPPP), implementation of best management practices (BMPs) identified in the SWPPP, and monitoring to ensure that effects on water quality are minimized. As part of this process, MID will implement multiple erosion and sediment control BMPs in areas with potential to drain to surface water (see Section 3.6, Geology, for a discussion of erosion and sediment control BMPs). These BMPs will be selected to achieve maximum sediment removal and represent the Best Available Technology (BAT) that is economically achievable. BMPs to be implemented as part of this environmental commitment may include, but are not limited to, the following measures. • Temporary erosion control measures (such as silt fences, staked straw bales/wattles, silt/sediment basins and traps, check dams, geofabric, sandbag dikes, and temporary revegetation or other ground cover) would be employed to control erosion from disturbed areas. • Drainage facilities in downstream off-site areas would be protected from sediment using BMPs acceptable to the Regional Water Quality Control Board (RWQCB). MID or its agent will perform routine inspections of the construction area to verify that the BMPs specified in the SWPPP are properly implemented and maintained. MID will notify its contractors immediately if there is a noncompliance issue and will require compliance.
WQ-1b	Implement a Spill Prevention and Control Program	MID or its contractor will develop and implement a spill prevention control and countermeasures program (SPCCP) to minimize the potential for, and effects from, spills of hazardous, toxic, or petroleum substances during construction activities for all contractors. The program will be completed before any construction activities begin. Implementation of this measure will comply with state and federal water quality regulations and minimize the effects of the Proposed Action. MID will review and approve the SPCCP before the onset of construction activities. MID will routinely inspect the construction area to verify that the measures specified in the SPCCP are properly implemented and maintained. MID will notify its contractors immediately if there is a noncompliance issue and will require compliance. The federal reportable spill quantity for petroleum products, as defined in the EPA's CFR (40 CFR 110), is any oil spill that (1) violates applicable water quality standards, (2) causes a film or sheen upon or discoloration of the water surface or adjoining shoreline, or (3) causes a sludge or emulsion to be deposited beneath the surface of the water or on adjoining shorelines. If a spill is reportable, the contractor's superintendent will notify MID, and MID will need to contact the appropriate safety and clean-up crews to ensure the SPCCP is followed. A written description of reportable releases must be submitted to the RWQCB. This submittal must include a description of the release, including the type of material and an estimate of the amount spilled, the date of the release, an explanation of why the spill occurred, and a description of the steps taken to prevent and control future releases. The releases will be documented on a spill report form. If a spill has occurred, MID will coordinate with responsible regulatory agencies to implement measures to control and abate contamination.
WQ-2	Implement Provisions for Dewatering	Before discharging any water from dewatering operations to surface water, MID or its contractors will obtain an NPDES permit and Waste Discharge Requirements (WDRs) from the RWQCB. Depending on the volume and characteristics of the discharge, coverage under the RWQCB's General Construction Permit or General Dewatering Permit is possible. As part of the permit, the permittee would design and implement measures as necessary so that the discharge limits identified in the relevant permit are met. As a performance standard, these measures will be selected to achieve maximum sediment removal and represent the BAT that is economically achievable. Implemented measures may include retention of water from dewatering operations until particulate matter has settled before it is discharged, use of infiltration areas, and other BMPs. Final selection of water quality control measures will be subject to approval by the RWQCB. MID will verify that coverage under the appropriate NPDES permit has been obtained before allowing dewatering activities to begin. MID or its agent will perform routine inspections of the construction area to verify that the water quality control measures are properly implemented and maintained. MID will notify its contractors immediately if there is a noncompliance issue and will require compliance.
Wetlands		
WET-1	Preservation of vernal pools and alkali rain pools.	Implementation of Environmental Commitments BIO-2a: Preconstruction Surveys/Avoid Effects on Vernal and Alkali Rain Pools and BIO-2b: Create, Restore, or Preserve Vernal Pools would minimize the extent of and compensate for adverse effects.
WET-2	Reduction of impacts to Waters of the United States from the discharge of fill	In GF Canal there are seasonal wetlands, including approximately 2 acres of freshwater marsh that would be affected. These effects would be offset by the development of freshwater marsh within GF Canal during operation and formation of seasonal wetlands within the swales during banking.

Comments on the Final Environmental Impact Statement

Reclamation's Notice of Availability of the Final EIS was published June 8, 2011 and the U.S. Environmental Protection Agency's Notice of Availability was published June 17, 2011. Copies of the FEIS were distributed to those who requested a copy. A press release was issued June 9, 2011 and the Final EIS was made available on Reclamation's website:

http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=3128

One comment letter on the Final EIS was received from the Environmental Protection Agency during the 30-day waiting period. The issue raised and Reclamation's responses follow:

Nature of Comment: The Environmental Protection Agency recommended that the additional discretionary conservation recommendations identified in the Biological Opinion to Reclamation (File Number 81420-2008-F-0279-1) dated April 26, 2011 issued by USFWS be considered for inclusion in the Environmental Commitments.

Agency Response: As stated in the April 26, 2011 Biological Opinion: "Section 7(a)(1) of the Act directs Federal agencies to utilize their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to implement recovery actions, to help implement recovery plans, to develop information, or otherwise further the purposes of the Act". As such, Reclamation in cooperation with MID will continue to seek funding opportunities to implement the discretionary conservation recommendations described in the Biological Opinion.

Northern Sacramento Valley Conjunctive Water Management Program

A Collaborative Planning Effort Co-Sponsored by
Glenn Colusa Irrigation District and the Natural Heritage Institute

Funded by the Bureau of Reclamation and
California Department of Water Resources

Final Report Public Briefing

4/12/2012

Introductory Perspectives

- Motivating Factors
- Regional Responses
- The Role of Groundwater

Motivating Factors: External Pressures

- Is Region Sustainable?
  - Environmental, Economic, Social
- The Delta
  - SWRCB Water Quality Control Plan Update (Flow Report stated Sac River 75% unimpaired flow to the Delta November-June)
  - Delta Species (smelt) dominate; Longfin Smelt Listing
  - Delta Stewardship Council
  - Bay Delta Conservation Plan
- System Re-operation:
  - SB x2-1 directs DWR to investigate climate change and conjunctive operations (see http://wwwdwr.water.ca.gov/system_reop/)
- Groundwater
  - State interest in groundwater regulation
  - Latest National Research Council recommended more regulation of groundwater
  - Scott Valley/Siskiyou County Groundwater Pumping Lawsuit

Regional Reponses

- Define Desired Regional Outcome
  - Sustainability of water, environment, economy
- Understand risks and pressures to region
  - Delta Flow Report, Export needs, Delta Plan
- Develop Regional Response and Solutions
  - IRWM, Stakeholder processes, Others?
- Develop Projects/Policies/Positions
- Understand outcomes of Solutions and weigh to Original Risk, Adaptive Management
- Response – Implement Solutions or Plan B?

The Role of Groundwater

- Sacramento Valley water demands have been satisfied for decades through conjunctive *use*
- Regional sustainability depends on conjunctive *management* in some form
- Groundwater investigations will happen, like surface water, how will regional interest and collaboration happen?

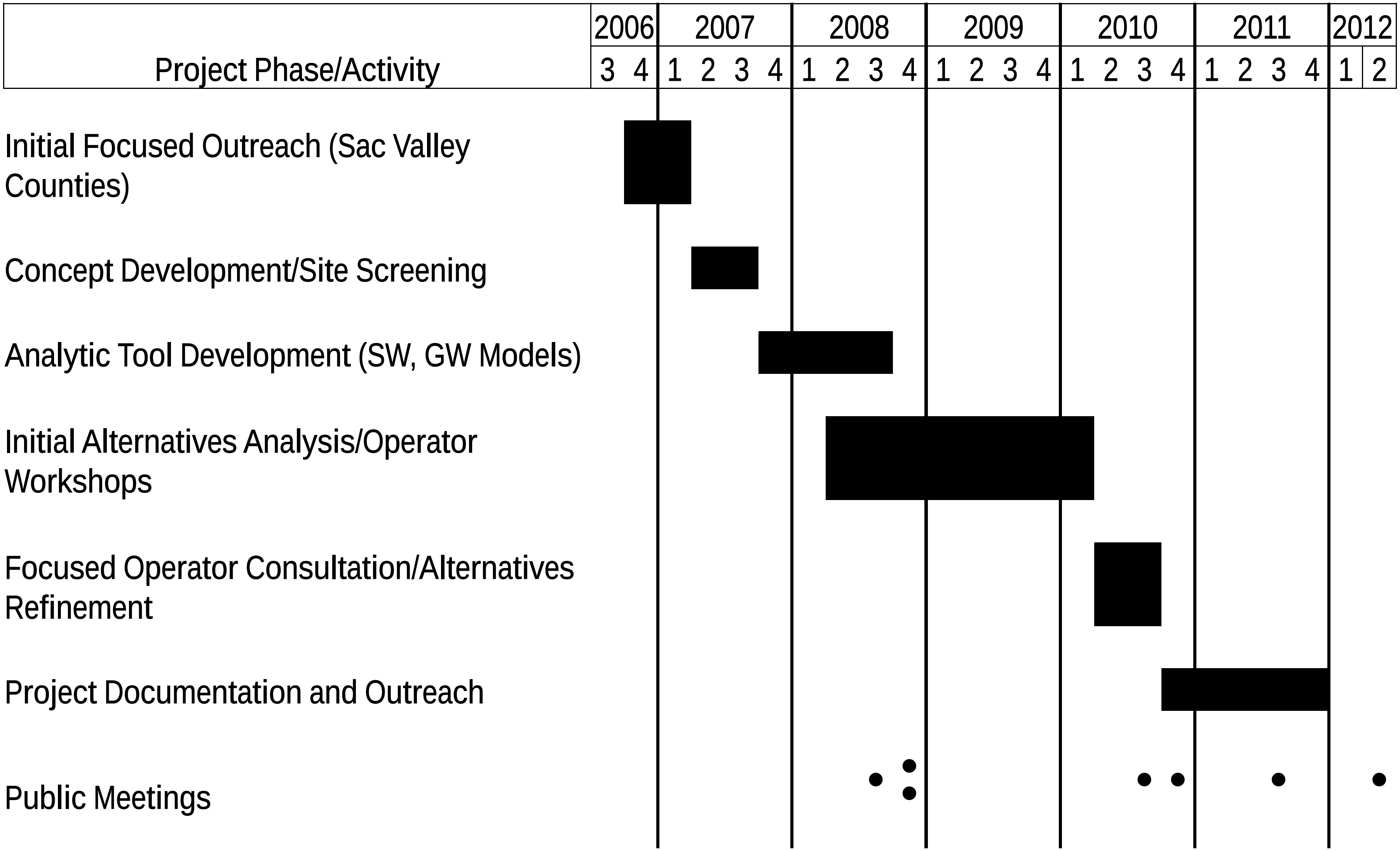
Briefing Topics

- High-Level Overview
- Core Conjunctive Management Concept
- Project Objectives and Principles
- Technical Approach and Analytic Tools
- Project Benefits
- Project Impacts
- Project Economics
- Conclusions and Recommendations

Overview:
Sponsors and Funding

- Jointly sponsored by Glenn-Colusa Irrigation District and the Natural Heritage Institute
- Funded by State and Federal grants:
  - Dept. of Water Resources: $500,000
  - Bureau of Reclamation: $700,000

Overview: Project Timeline



Project Phase/Activity

Initial Focused Outreach (Sac Valley Counties)

Concept Development/Site Screening

Analytic Tool Development (SW, GW Models)

Initial Alternatives Analysis/Operator Workshops

Focused Operator Consultation/Alternatives Refinement

Project Documentation and Outreach

Public Meetings

Overview: What Was Studied?

- Can additional water supplies be generated for use within the Sacramento Valley through the conjunctive management of existing surface water reservoirs and groundwater aquifers?
  - Lake Shasta and Lake Oroville
  - Intermediate aquifer and deep aquifer
  - Water used for environmental enhancement in the Sac and Feather Rivers and for agricultural water supply

Overview: What Was Learned?

- Traditional groundwater banking…storing surplus surface water underground and extracting it when needed…is not workable in the Sacramento Valley
  - Available aquifer storage capacity is inadequate
- Re-operation of existing storage reservoirs to draw them down further going into the refill season can generate additional water supplies
  - Evacuated reservoir space captures surplus stream flow
  - Reservoir “payback” is needed infrequently, when surplus stream flow is inadequate

Overview: What Was Learned?

- Reservoir “payback” by not making reservoir releases that would otherwise be made and pumping groundwater instead is feasible
  - Groundwater pumping required very infrequently
- Reservoir payback by temporarily idling crops to reduce reservoir demands is not efficient or cost-effective
  - Timing issues/idling cannot be turned on/off

Overview: Benefits to Groundwater

	Groundwater Pumping Capacity (thousand acre-feet)			
Scenario	Project	New Yield to Ag	Groundwater Pumped	**Net Gain to Groundwater**
1,3,4	CVP	1,148	246	**902**
1,3,4	SWP	820	246	**574**
2	CVP	1,804	738	**1,066**
2	SWP	1,886	574	**1,312**

Overview: What Was Learned?

- Impacts to existing groundwater users and streams is negligible
  - Payback pumping appreciable but required very infrequently
- As evaluated, the conjunctive management alternatives evaluated are not economically feasible
  - Benefits based solely on “in-Valley” value of water
  - No monetary value attached to the environmental benefits

Overview: Conclusions

- Further investigation is warranted but depends on regional interest and collaboration
  - Potential component of Integrated Regional Water Management Plans?
- Certain technical refinements recommended if further investigation undertaken, including climate change sensitivity

Core Concept:
Re-operate Existing Reservoirs

- Draw reservoirs down further going into the winter refill season
  - Produce additional water supply by capturing surplus surface flows
  - Increases risk that reservoirs will not refill
- When they do not refill, recover reservoirs by substituting alternative supplies or reducing water demands
  - Referred to as “reservoir payback”

Reservoir Payback Mechanisms

- Extract groundwater “banked” in prior years (not feasible)
- Reduce reservoir releases that would otherwise be made from reservoirs
  - Substitute with pumped groundwater
  - Temporary crop idling (on a voluntary, compensated basis)

Project Objectives

- Enhance ecosystem functions in the Sacramento and Feather Rivers by making additional reservoir releases for specific purposes
- Improve local (in-Valley) water supply reliability, particularly during times of scarcity
  - Reduce reliance on groundwater pumping
  - Reduce water shortages/lost production

Enhance Ecosystem Functions

- Geomorphic processes: sediment transport, bed mobilization and scour, etc.
- Floodplain inundation: provide habitat for rearing of juvenile salmon
- Spring pulse flows: enhance rearing and out-migration of juvenile salmon
- Riparian habitat

Specific flow rates, timing and durations developed for each objective, along with dynamic prioritization

Improve In-Valley Water Supply

- Historical unmet agricultural surface water demands <u>used as surrogates</u> for additional in-Valley water needs
  - Central Valley Project (CVP) water supply contractors along Tehama-Colusa Canal
  - Feather River water rights holders subject to shortages in dry years
  - Minimize crop idling and groundwater pumping

Additional water supplies could be used for any purpose.

Project Principles

- Honor all existing CVP and SWP obligations and operational requirements
- Achieve net environmental benefits recognizing potential for tradeoffs
- Hold existing groundwater users harmless by avoiding, minimizing, mitigating impacts
- Try to generate net positive economic benefits

Technical Approach and Analytic Tools

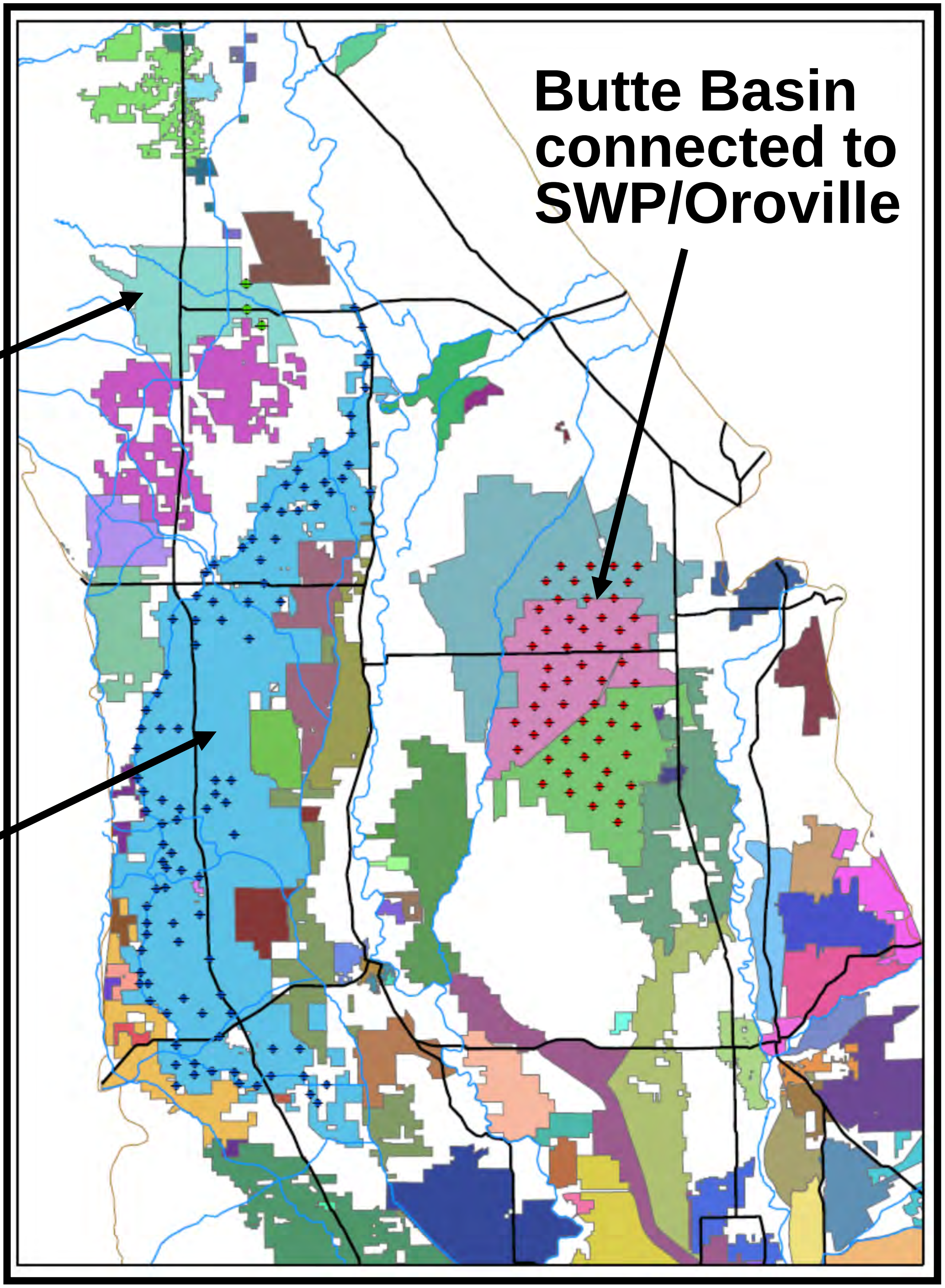
- Site screening and selection
- Groundwater and surface water models
- Project scenarios

Initial Site Screening

Attractive Site Features

- Groundwater conditions
  - Available aquifer storage space
  - Viable recharge mechanism
  - Productive groundwater wells
  - Suitable GW quality
- Surface water conditions
  - Reliable surface water supplies
  - Connection to CVP, SWP or other reservoirs that could be re-operated
  - Dual SW and GW use option
- Impacts/mitigation
  - Isolation from important surface streams
  - Isolation from existing groundwater production wells
  - Ability to mitigate or compensate impacts that cannot be avoided

Nine Sites Evaluated; Three Promising Sites Identified



Orland Unit connected to Stony Creek Reservoirs

Glenn-Colusa ID connected to CVP/Shasta

Butte Basin connected to SWP/Oroville

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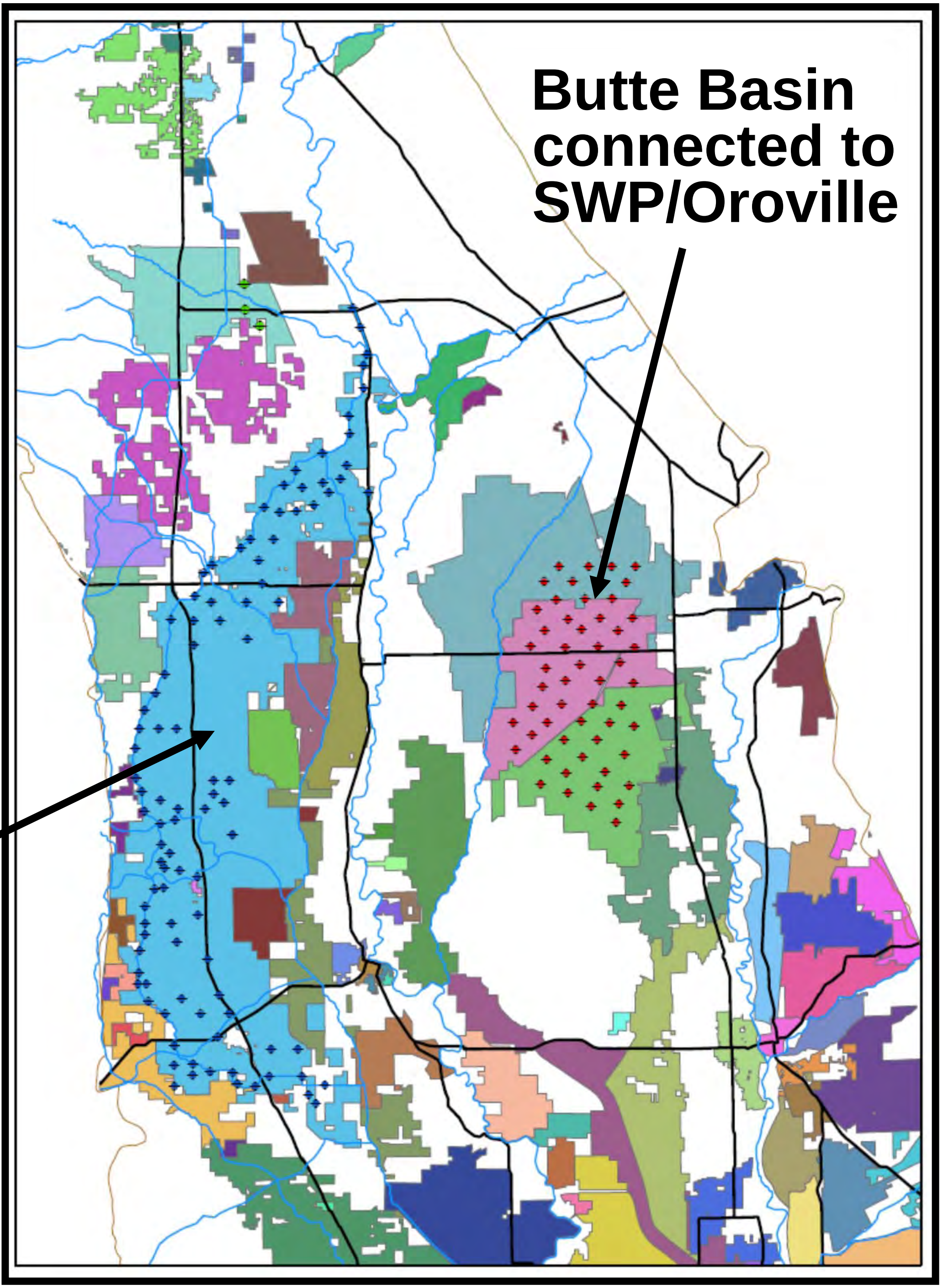
Two Sites Selected for Modeling



Butte Basin connected to SWP/Oroville

Glenn-Colusa ID connected to CVP/Shasta

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Modeling Requirements

- Honor existing CVP and SWP operations
- Account for stream-aquifer interaction and impacts to existing pumpers
- Fast and flexible model operation
  - Test many configurations and scenarios
  - "Gaming" with Project Operators

Conclusion: Use separate but coordinated SW and GW models.

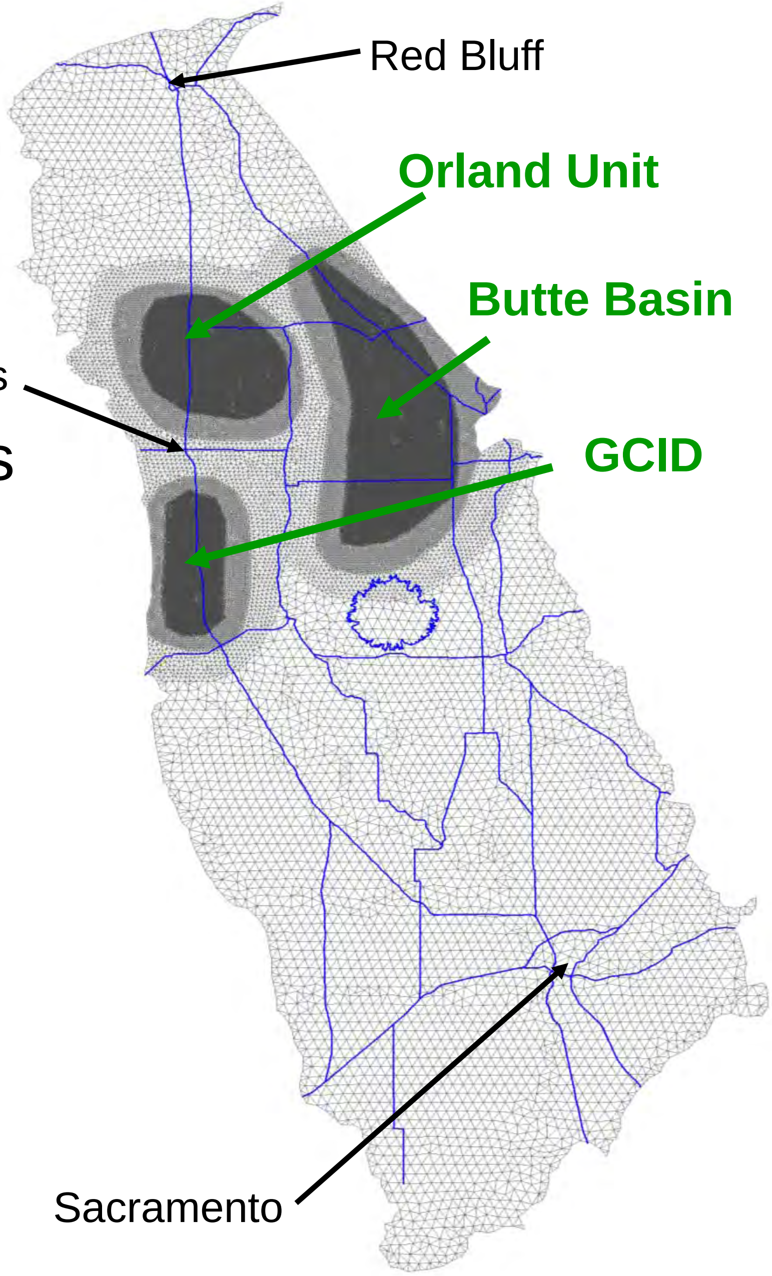
Surface Water Model

- Spreadsheet-based model designed for incremental analysis of CALSIM II outputs
  - Honor existing CVP and SWP operations
- Based on 1922 through 2003 hydrology
  - Climate variability not evaluated at this stage of study
- Simulations “driven” by additional target deliveries
  - Ecosystem flow targets in Sacramento and Feather Rivers
  - Unmet Sacramento Valley agricultural demands
- Uses generalized SW-GW interaction functions derived from GW model

Groundwater Model

- Regional scale with high spatial detail
  - 5,950 square miles
  - 88,922 surface nodes
  - 7 vertical layers
- Aquifer properties based on analysis of more than 1,000 production well records
- Calibration
  - Static calibration for year 2000
  - Water levels from 257 monitoring wells
- 1982 - 2003 hydrology

(Model has been developed further since being used for this project)



Parameters Defining Project Scenarios

- Maximum reservoir “payback” capacity
  - Maximum volume of groundwater pumping to be called on, as needed, to repay reservoirs when they don’t refill with surplus runoff
  - Defines the scale of the conjunctive operation
- Groundwater pumping period
  - “Summer” (May through August)
  - “Fall” (September through November)
  - “Summer and Fall” (May through November)
  - Influences the intensity of pumping and nature of impacts

Project Scenarios Evaluated

Scenario	Groundwater Pumping Capacity (thousand acre-feet)			Pumping Season
	GCID (CVP)	Butte Basin (SWP)	Total	
1	100	50	150	summer
2	200	100	300	summer
3	100	50	150	fall
4	100	50	150	summer & fall

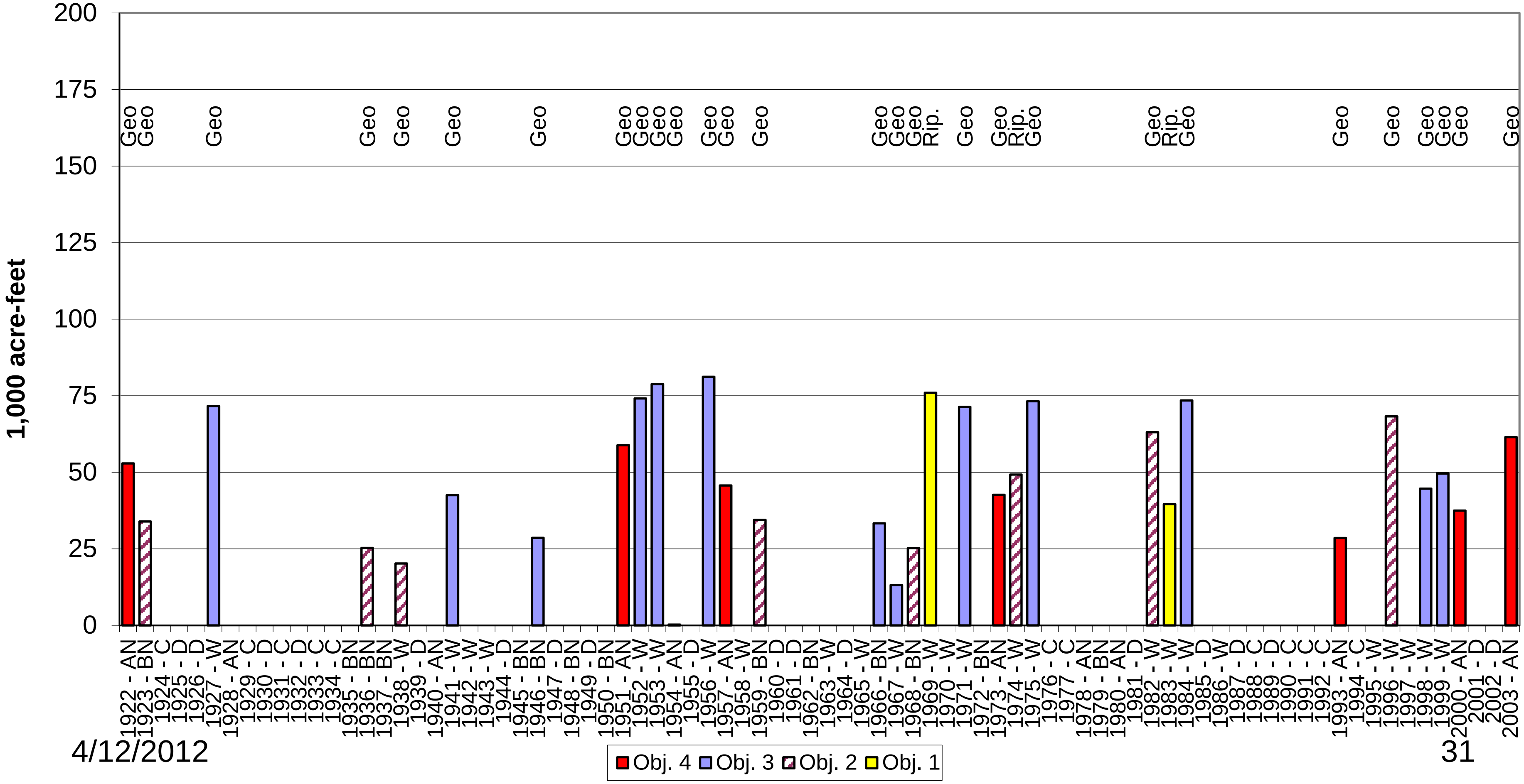
All scenarios modeled with an existing (shallow) and new (deep) well field to reveal range of potential impacts to streams and existing pumpers.

Results for Butte Basin—Scenario 2 (100 TAF Project Pumping Capacity)

- Environmental flow releases
- Agricultural deliveries
- Reservoir refill from surplus surface water and from groundwater pumping
- Oroville storage

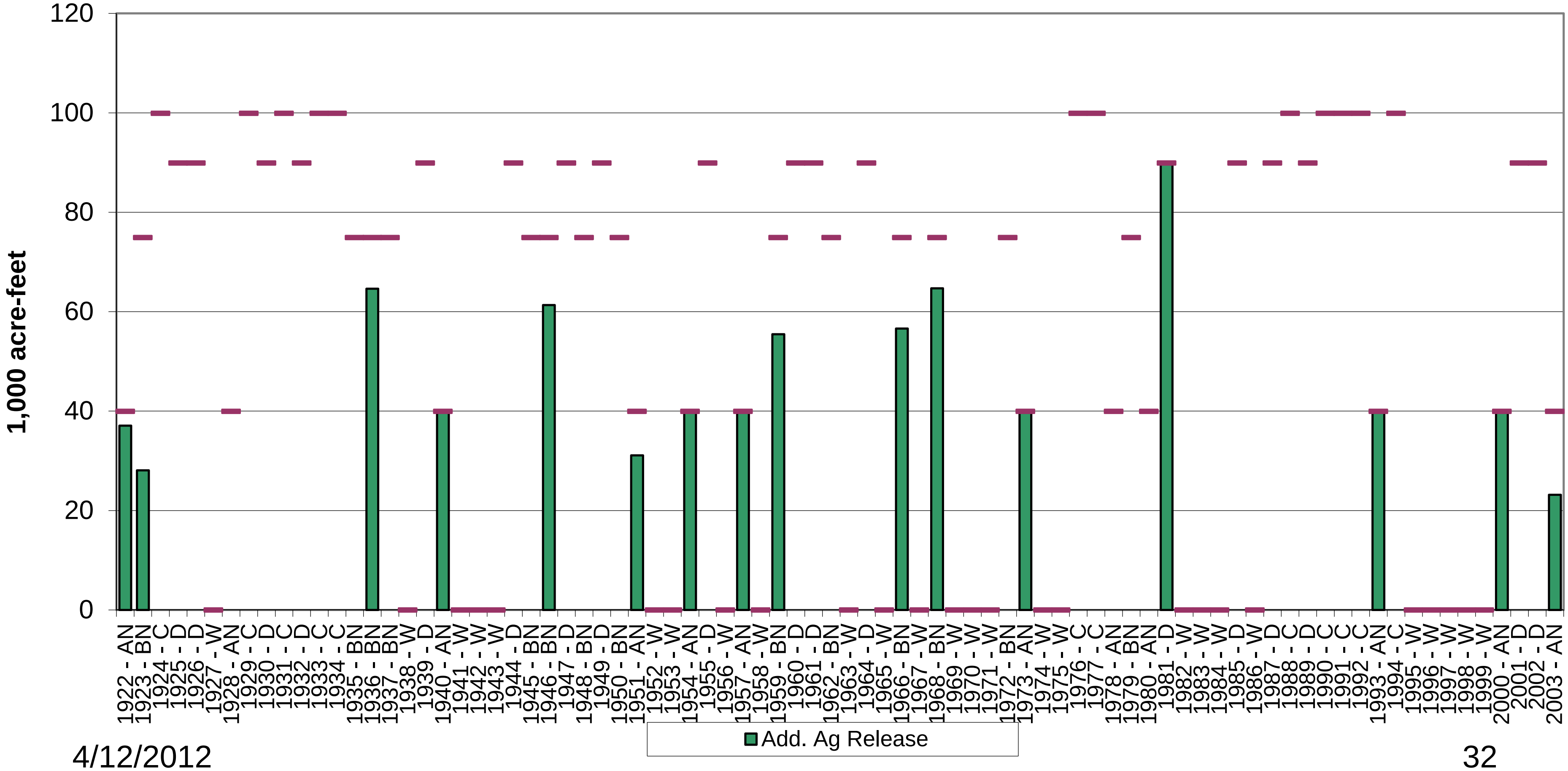
Results for Butte Basin—Scenario 2 (100 TAF Project Pumping Capacity)

Environmental Flow Releases

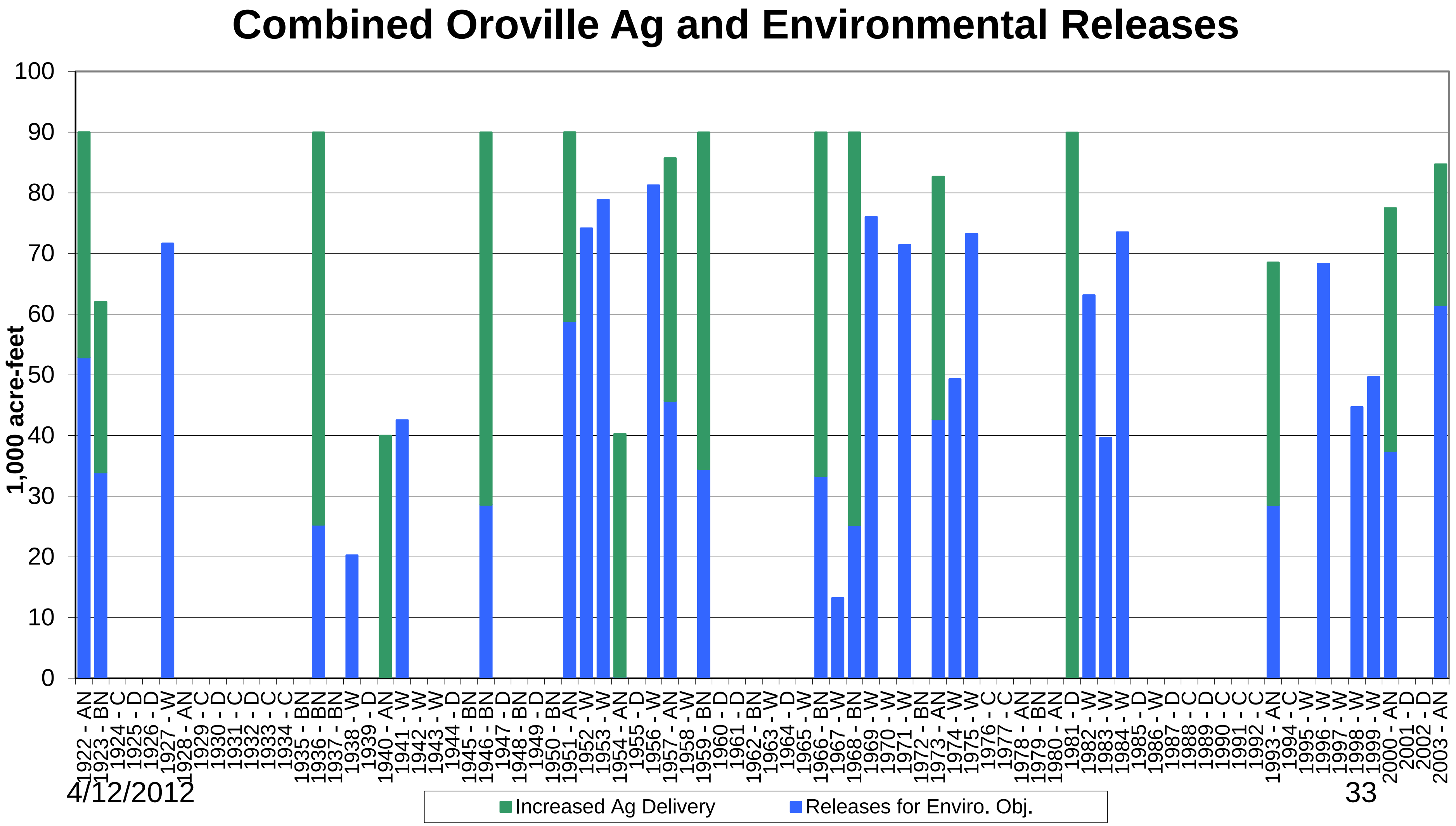


Results for Butte Basin—Scenario 2 (100 TAF Project Pumping Capacity)

Feather River Unmet Ag Demand and Additional Delivery

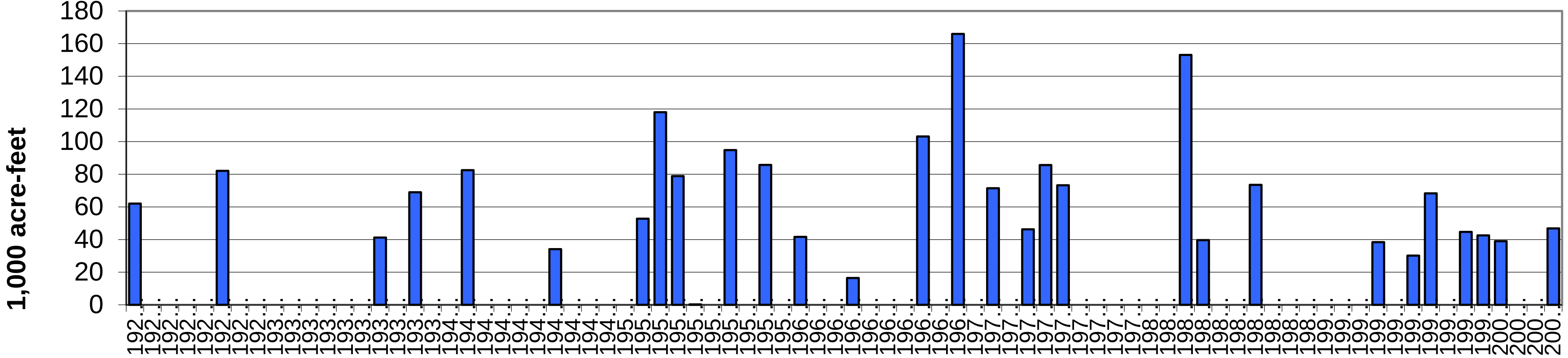


Results for Butte Basin—Scenario 2 (100 TAF Project Pumping Capacity)

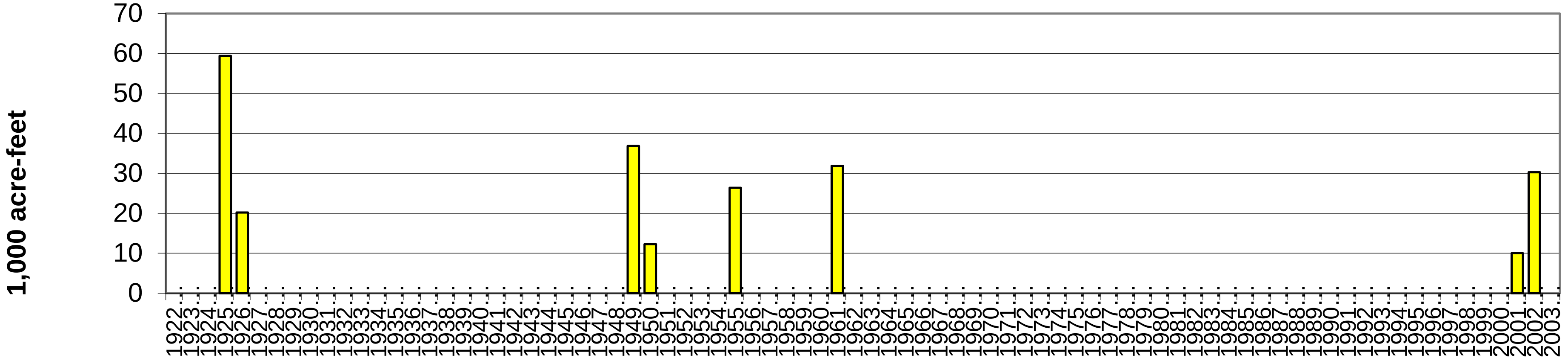


Results for Butte Basin—Scenario 2 (100 TAF Project Pumping Capacity)

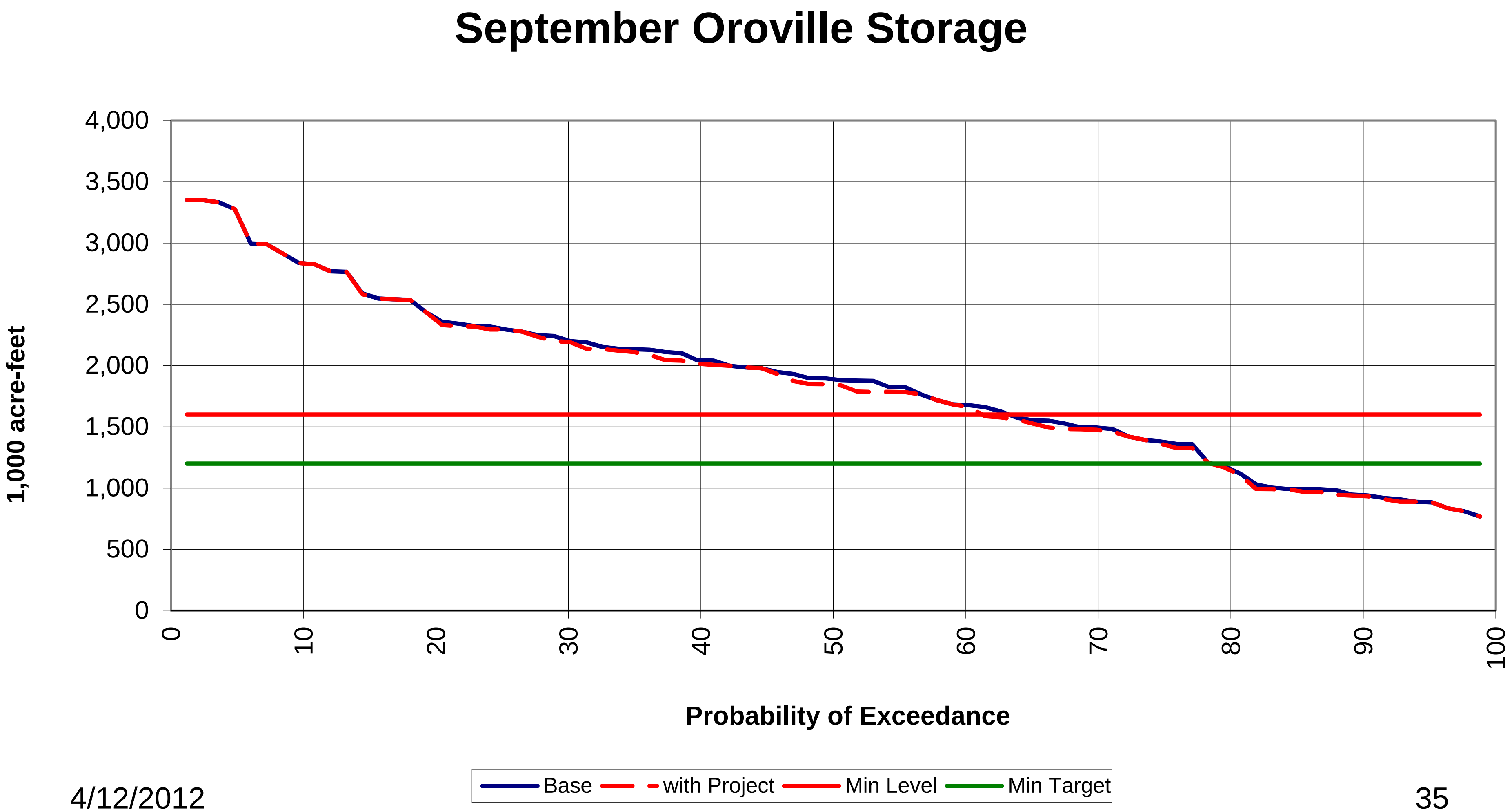
Oroville Refill from Surplus Inflow



Butte Basin Project Pumping



Results for Butte Basin—Scenario 2 (100 TAF Project Pumping Capacity)



Summary of Model Results
Project Benefits

Scenario(s)	Project/System	Payback Pumping Capacity (TAF)	Environmental Benefits			Agricultural Benefits		
			Number of Years	Avg in Yrs of Occurrence (TAF)	Avg Over All Yrs (TAF)	No. Yrs.	Avg in Yrs of Occurrence (TAF)	Avg Over All Yrs (TAF)
1, 3 and 4	GCID/CVP Lake Shasta-Sac R	100	23	46	13	24	46	14
1, 3 and 4	Butte Basin/SWP Lake Oroville-Feather R	50	28	21	7	30	27	10
2	GCID/CVP Lake Shasta-Sac R	200	40	96	47	24	75	22
2	Butte Basin/SWP Lake Oroville-Feather R	100	44	43	23	30	52	20

Summary of Model Results
Reservoir Refill

Scenario(s)	Project/System	Payback Pumping Capacity (TAF)	Surplus Surface Water Number of Years	Surplus Surface Water Avg in Yrs of Occurrence (TAF)	Surplus Surface Water Avg Over All Yrs (TAF)	Project Groundwater Pumping No. Yrs.	Project Groundwater Pumping Avg in Yrs of Occurrence (TAF)	Project Groundwater Pumping Avg Over All Yrs (TAF)	Project Groundwater Pumping Maximum Year (TAF)
1, 3 and 4	GCID/CVP Lake Shasta-Sac R	100	29	70	24	4	70	4	98
1, 3 and 4	Butte Basin/SWP Lake Oroville-Feather R	50	37	32	14	6	44	3	50
2	GCID/CVP Lake Shasta-Sac R	200	35	139	58	6	123	9	198
2	Butte Basin/SWP Lake Oroville-Feather R	100	43	72	36	8	75	7	100

Project Impacts Due to Additional Groundwater Pumping

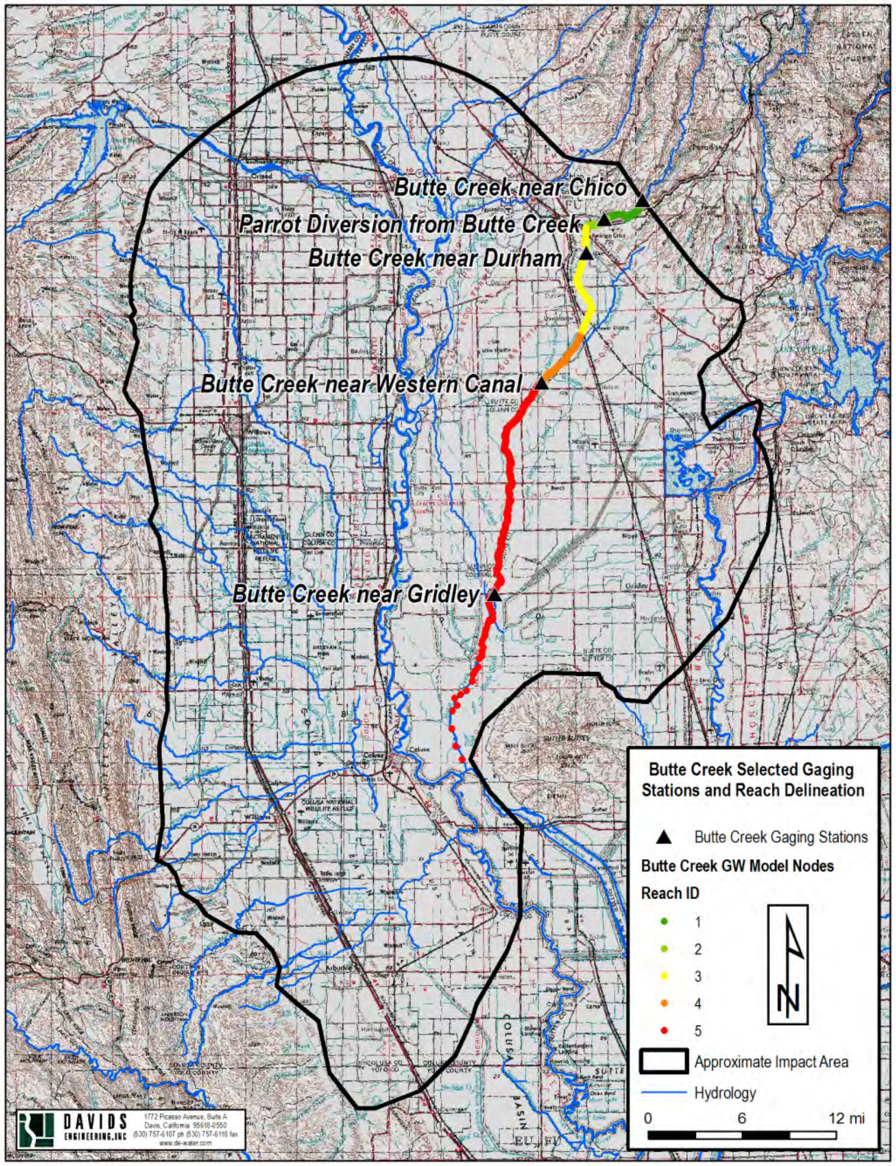
- Stream flow reduction
  - Butte Creek in affected area
  - Other critical streams not in affected areas
  - Ephemeral streams not analyzed
- Groundwater levels and existing wells
  - Well yield impacts
  - Incremental pumping costs (due to additional lift)

Peak Monthly Effects on Streamflow from Payback Pumping

	Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Stream	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**	**Existing (cfs)**	**New (cfs)**
All Streams[a]	54	53	111	105	80	90	64	65
Butte Creek	13	12	72	69	50	48	39	33
Sacramento River – GCID to Wilkins Slough	42	37	32	28	16	18	16	15
Feather River	3	3	6	6	4	4	4	4
Little Chico Creek	3	3	6	5	4	3	4	3
Salt River	1	5	5	8	2	5	2	5
Stone Coral Creek	6	9	11	15	7	10	6	9
Stony Creek	4	5	7	7	4	6	4	4

Butte Creek Streamflow Reduction

- Develop baseline flow from available gauging stations
- Synthesize “with-project” flows based on cumulative reductions in streamflow from changes in stream leakance from GW model



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Butte Creek Impacts

- No impact in upper reaches (primary spawning and holding areas)
- Greatest flow reduction in Jan. – Mar.
  - During times of highest discharge
- Greatest % reduction in summer/early fall
  - Spring-run have already migrated
  - Steelhead just beginning to enter stream
- Rarely drops below in-stream standards
  - June during early '90s drought
- Tradeoffs between Butte Creek impacts and main stem benefits
- Potential to Reoperate with PGE and increase releases from into Butte Creek, exchange reoperated flows from Oroville to PGE Projects

Interference Drawdown Due to Project Pumping

	Interference Drawdown (ft)				
Pumping Scenario	Min	Max	Mean	Median	Std. Dev.
300 TAF Summer Pumping, New Well Field	0.0	13.6	0.5	0.3	0.7
300 TAF Summer Pumping, Existing Well Field	0.0	8.3	0.4	0.2	0.6
150 TAF Summer Pumping, New Well Field	0.0	6.2	0.3	0.2	0.4
150 TAF Summer Pumping, Existing Well Field	0.0	5.4	0.3	0.2	0.4
150 TAF Fall Pumping, New Well Field	0.0	7.0	0.4	0.2	0.4
150 TAF Fall Pumping, Existing Well Field	0.0	6.1	0.4	0.2	0.5
150 TAF Summer & Fall Pumping, New Well Field	0.0	5.9	0.4	0.2	0.4
150 TAF Summer & Fall Pumping, Existing Well Field	0.0	5.0	0.4	0.2	0.5

Conclusions

- Traditional groundwater banking…storing surplus surface water underground and extracting it when needed…is not workable in the Sacramento Valley
  - Available aquifer storage capacity is inadequate
- Re-operation of existing storage reservoirs to draw them down further going into the refill season can generate additional water supplies
  - Evacuated reservoir space captures surplus streamflow
  - Reservoir “payback” is needed infrequently, when surplus streamflow is inadequate

Conclusions, (cont.)

- Reservoir “payback” by not making reservoir releases that would otherwise be made and pumping groundwater instead is feasible
  - Groundwater pumping required very infrequently
- Reservoir payback by temporarily idling crops to reduce reservoir demands is not efficient
  - Timing issues/idling cannot be turned on/off

Conclusions, (cont.)

- Impacts to existing groundwater users and streams appear to be manageable
  - Payback pumping appreciable but required very infrequently
- As evaluated, the conjunctive management alternatives evaluated are not economically feasible
  - Benefits based solely on “in-Valley” value of water
  - No monetary value attached to the environmental benefits

Conclusions, (cont.)

- Further investigation may be warranted but depends on regional interest and collaboration
  - Potential component of Integrated Regional Water Management Plans?

Recommended Further Study

- Reconcile tradeoffs among environmental water uses in reservoir operations
- Refine reservoir operation rules
- Refine payback strategies and costs
- Develop system-wide accounting conventions
- Update models
- Evaluate effects of climate change/variability

Questions?

The Delta Plan

Ensuring a reliable water supply for California, a healthy Delta ecosystem, and a place of enduring value

2013

DELTA STEWARDSHIP COUNCIL

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STATE OF CALIFORNIA

Edmund G. Brown, Jr., Governor

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Executive Summary

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Executive Summary

The Sacramento-San Joaquin River Delta is the grand confluence of California's waters, the place where the state's largest rivers merge in a web of channels—and in a maze of controversy. The Delta is a zone where the wants of a modern society come into collision with each other and with the stubborn limitations of a natural system. In 2009, seeking an end to decades of conflict over water, the Legislature established the Delta Stewardship Council with a mandate to resolve long-standing issues. The first step toward that resolution is the document you have before you, the Delta Plan.

Though more than 50 miles inland from the Golden Gate, Delta waters rise and fall with ocean tides. The Delta is in fact the upstream, mostly freshwater portion of the San Francisco Estuary, the largest estuarine system on the West Coast of the Americas, and one of California's prime natural assets. It is a major stop on the Pacific Flyway and the portal through which important fish species, including anadromous Chinook salmon, pass on their way to and from their spawning grounds in the interior.

The system of waters in which the Delta is so central has changed dramatically since California became a state. Rivers have been dammed and aqueducts built. Natural flows and fluxes have been disrupted to support cities and make the Central Valley the fruit basket and salad bowl of the nation. Approximately half of the water that historically flowed into and through the Delta is now diverted for human use, never reaching the sea. Much of this diversion occurs at points upstream, before the rivers come down to the Delta; but the last and largest draws take place in the Delta itself. On the southeast edge of the region, near Byron, two sets of mighty pumps extract water for shipment as far south as San Diego. Two-thirds of California's people and 4.5 million acres of farmland receive some part of their water from the Delta.

The Delta landscape we know is itself the result of a great transformation, from a primeval wetland complex to an archipelago of diked islands, where soils that once grew vast thickets of tules now yield bountiful corn, alfalfa, tomatoes, and many other crops. The Delta is home to about 12,000 people on farms and in small historic communities, and to about half a million in the larger cities that are

pressing into the region from the fringe. More millions come to it for boating, fishing, hunting, bird watching, even windsurfing on its 700 miles of channels. Steeped in history, combining notes of the American heartland and of Holland, the Delta looks and feels like no other place in California. This is a land that people love.

It is not doing so well.

The very shape of the modern Delta is in danger. Farming of peat-rich ground like this always leads to oxidation, the literal vanishing of soil, and thus to subsidence. Many Delta islands now lie 15 feet or more below sea level and depend on aging dikes to prevent the water in adjacent channels from pouring in. Higher river flows in winter or spring, predicted results of climate change, will add to the pressure, and a great earthquake, sooner or later, will shake the region like a paint can on a mixer. Encroaching urbanization, meanwhile, puts more people and property on dangerous ground.

After years of slow decline, the condition of the Delta's watery ecosystem, as measured especially by the population of wild salmon and other native fishes, has gone critical. The list of causes begins, but does not end, with all those water withdrawals, a kind of tax that leaves the system in a condition of chronic drought. The specific, peculiar manner in which the last large gulps of water are withdrawn adds to the ecological cost. The continual introduction of alien aquatic species from around the world is altering the web of life, often at the expense of native and other valued species. Pollution from the vast and busy watershed does its share of harm.

Today, all those who depend on or value the Delta are, in a word, afraid. Delta residents face the possibility of floods from the east when the rivers flow strongly and of salinity intrusion from the west if they flow too feebly. Fishermen, both commercial and recreational, fret about the future of salmon and other species. Water suppliers that receive water from the Delta find those supplies insecure, subject to interruption by weather vagaries, levee failures, or pumping restrictions imposed in the desperate attempt to stem the decline of fish.

> ***Steeped in history, combining notes of the American heartland and of Holland, the Delta looks and feels like no other place in California. This is a land that people love.***
>
> ***It is not doing so well.***

The Coequal Goals, the Delta Stewardship Council, and the Delta Plan

Since the middle 1980s, California has been looking for ways to secure the natural and human values of the Delta while maintaining its place in the state's water plumbing. These efforts have generally started in hope and ended in impasse. In recent years environmentalists turned to the courts, using the blunt tool of the federal Endangered Species Act to force curtailment of water exports at certain times. In reaction, water suppliers south of the Delta have complained of "regulatory drought."

In 2009 the Legislature made its latest, most determined bid to find solutions, passing the Delta Reform Act and associated bills. First and foremost, it declared that State policy toward the Delta must henceforth serve two "coequal goals":

- Providing a more reliable water supply for California, and
- Protecting, restoring, and enhancing the Delta ecosystem.

These goals, the Legislature added, must be met in a manner that:

- Protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

By affirming the equal status of ecosystem health and water supply reliability, the Legislature changed the terms of the conversation. It changed them further with the following pronouncement: "The policy of the state of California is to reduce reliance on the Delta in meeting California's future water supply needs." Here was recognition that, for the sake of the water system and the Delta both, a partial weaning of the one from the other is required.

The Delta Stewardship Council is the body entrusted with giving practical meaning to these directives. Publication of this Delta Plan completes its first assignment. The product of eight drafts, almost 100 public meetings, and nearly 10,000 comments, the Delta Plan pulls together in one place the steps that need to be taken to meet the coequal goals—measures that, in one way or another, could affect almost everyone in California. The Plan is to be revised every 5 years, or sooner as circumstances change.

The Delta Plan contains 87 provisions, some broad and some narrowly technical, some novel, some commonsensically familiar. What, in essence, does the Plan propose be done differently? At the risk of oversimplification, we can say that it asks California and Californians to do six large things:

- In order to improve and secure our water supply, while taking pressure off the Delta, we must use water more efficiently in cities and on farms, and develop alternative, usually local, sources.
- We must also get much better at capturing and storing the surplus water that nature provides in the wettest years, building reserves that can be drawn on in dry ones.
- To revitalize the Delta ecosystem, we must provide adequate seaward flows in Delta channels, on a schedule more closely mirroring historical rhythms: what the Plan calls natural, functional flows.
- We must also bring back generous wetlands and riparian zones in the Delta for the benefit of fish and birds.
- To preserve the Delta as a place, we must restrict new urban development to those peripheral areas already definitely earmarked for such growth, while supporting farming and recreation in the Delta's core.
- And we must floodproof the Delta, as far as feasible, mainly by improving levees and by providing more overflow zones where swollen rivers can spread without doing harm.

What about today's headline issue concerning the Delta—the proposed construction of tunnels to improve the way water destined for export southwards reaches the pump intakes near Byron? This initiative is part of what is called the Bay Delta Conservation Plan (BDCP). The BDCP is a different and more narrowly focused undertaking than the Delta Plan, into which, if certain conditions are met, it will be fused (see section, A Better System: Delta Conveyance).

The Delta Plan is *California's* plan for the Delta, prepared in consultation with, and to be carried out by, all agencies in the field: the State Water Resources Control Board, ultimate arbiter of water rights and water quality; the California Department of Water Resources, the state's water planner and also operator of the great State Water Project; the California Department of Fish and Wildlife, responsible for the welfare of the living system of the Delta; the Delta Protection Commission, which oversees land use and development on low-lying Delta islands; and many more agencies, State and local. Add to the list federal players like the Bureau of Reclamation, which runs the Central Valley Project; the U.S. Fish and Wildlife Service; the National Marine Fisheries Service; and the U.S. Army Corps of Engineers. Their cooperation has been promised, and it is vital.

The working parts of the Plan are 73 *Recommendations* and 14 *Policies*. *Recommendations* call attention to tasks being done or to be done by others. *Policies* are legal requirements that anyone undertaking a significant project in the Delta must meet. See the sidebar, From Plan to Reality, for more on the mechanics of realizing the Plan and pages ES-15 to ES-35 for a survey of all 87 provisions.

Where Is the Money?

The Legislature sees "adequate and secure funding" as a need "inherent in the coequal goals." In order to know what this entails, we need to form a clearer picture of the costs of the work now proposed for the Delta or on its behalf and how those costs might be met. This first edition of the Delta Plan proposes research toward that clarity.

FROM PLAN TO REALITY

The Legislature instructed the Delta Stewardship Council to "direct efforts across state agencies." This "direction" has three distinct aspects.

First of all, the Council is to **coordinate**. It will chair a high-powered committee dedicated to implementing the Plan. The heads of key State and local agencies will be at that table, together with federal representatives. This body will meet for the first time in fall 2013. Agency staffs will work with that of the Council daily.

Second, the Council is to **keep track of progress**. Using specific performance metrics contained in the Plan, and guided by the Delta Science Program (see sidebar, Science at the Center), it will monitor what is actually being done toward Plan goals, and what changes of course may be indicated. The results will be widely publicized.

Third, in certain key areas, the Council can be called upon to **block damaging actions**. The Plan provisions that can trigger this authority are called Policies. To avoid premature encroachment on the work of other agencies, the Legislature devised an indirect path leading to Council intervention.

Actions subject to these Policies are called "covered actions," but the Council itself cannot declare an action to be covered. It is the proposing agency that makes this determination. Legal standards apply, however, and if an action is questionably deemed not to be covered, the Council or any other party can take the agency to court.

Once an action is determined to be covered, the proposing agency must make sure it is in line with the Policies of the Delta Plan, filing a Certification of Consistency with contents specified in Delta Plan **Governance Policy 1**. If the agency says the action is consistent but another party or citizen thinks it is not, the opponent can then appeal to the Delta Stewardship Council. A Council member or the Council's Executive Officer may initiate the appeal.

SCIENCE AT THE CENTER

The Delta Reform Act mandates that the Delta Plan be based on the best available scientific knowledge of our day. It must, moreover, be open to change as knowledge changes—and as paper proposals meet the test of reality. The results of every action are to be closely tracked, so that corrections can be made in a timely way—a process, much discussed but not sufficiently practiced, known as adaptive management.

To be more than a buzzword, adaptive management must bring two things to bear: new information, and a readiness to let new information disrupt old plans. Both, in the past, have been in scant supply.

Though Delta knowledge has expanded hugely in recent years, it is often a challenge to pull that data together and draw conclusions from it. Studies are done by different agencies for specific purposes and in narrow contexts; findings can be hard to integrate. The Delta Science Program, a function of the Council, will seek to overcome these gaps, linking the whole community of scientists at work. Guided by a top-flight Delta Independent Science Board, it will prepare, by December 31, 2013, a companion to the Delta Plan called the Delta Science Plan (**Governance Recommendation 1**).

The Delta Science Plan will propose a collaborative structure for doing science in the Delta. It will suggest ways of improving communication, resolving conflicting results, and accommodating uncertainty. It will offer priorities: how to apportion attention between immediate practical questions, on the one hand, and research aimed at increasing long-term understanding, on the other. It will sketch a more integrated approach to monitoring, so that results from different settings can be compared, and consider how computer modeling of the intricate Delta system might be improved.

Once a year, the Council will bring scientists together to assess what has been learned and what changes in ongoing plans and projects the new knowledge may suggest. Another conference? Yes, but with a difference: These findings will feed directly into ongoing refinement of the Delta Plan.

First step is an inventory: How much is now actually being spent, by all the agencies involved, that can be chalked up to furthering the coequal goals? Second comes an assessment of costs: How much will it take to carry out the projects and programs described in the Delta Plan, and what might the sources of support be for each one? The third step must be a comparison of resources and needs, and a reckoning of gaps: What key elements lack probable funding, and what might be done to fill these holes? (**Funding Principles Recommendations 1 through 3**.)

Providing a More Reliable Water Supply for California...

The Delta's contribution to the overall statewide water supply is smaller than many people think. The proportion drawn directly from the Delta, mostly through the pumps near Byron, is only about 8 percent of the total. The bulk of California's water comes from more local sources, and always has.

Nevertheless, the Delta supply is important to many regions. Southern California imports about 25 percent of its water via the Byron pumps. The Tulare Lake Basin, the southern end of the Great Central Valley, gets 27 percent of its water by that route. Even the San Francisco Bay Area takes 16 percent of its supply from Delta pumps. On a more local scale, several water suppliers rely entirely on the Delta, and others have become dependent on this one overtaxed source to a risky degree.

In addition to water pulled directly from the Delta, a great deal is drawn from the Delta's tributary streams before they come down to sea level. San Francisco Bay Area cities reach far inland to tap the Tuolumne and Mokelumne Rivers in the Sierra Nevada, taking 27 percent of their water needs from these sources. Parts of the Central Valley tributary to the Delta get all of their water from that watershed by definition, as do the people and farms of the Delta itself. (See also sidebar, The Problem with Numbers.)

> ***California water planning is full of good intentions. If the laws and policies that are now on the books were consistently carried out, the state's water system—including that part that is tied to the Delta—would work much better.***

The Delta Plan addresses water supply on three scales: California-wide, on the Delta watershed level, and in the areas that receive water from the Delta pumps. (See Figure ES-1, The Delta Watershed and Areas Receiving Delta Water.)

California water planning is full of good intentions. If the laws and policies that are now on the books were consistently carried out, the state's water system—including that part that is tied to the Delta—would work much better. The Delta Plan calls on *all* water suppliers to obey the many laws and guidelines that exist, and on the State's regulatory agencies to insist on compliance (**Water Resources Recommendation 1**).

THE PROBLEM WITH NUMBERS

In talking of California water, we put trust in numbers: flows, usages, capacities, trends. But some seemingly solid and much-quoted figures are little more than guesses. By and large, we do not truly know how much water we are using or how much we are saving through conservation efforts. We know less than we should about Delta inflows and outflows. We know little about groundwater except that water tables in too many places are dropping. What information is available is often packaged in inscrutable ways. The Delta Plan asks all the agencies and water suppliers involved to provide or demand better information, and to communicate it better (**Water Resources Policy 2, WR Recommendations 16 through 19**).

Whatever the outcome of some current debates, California's next large increment of water supply will not come from major new engineering but from water conservation, recycling, local stormwater capture, and reasonable use of aquifers (see section, A Better System: Storing Floods to Ride Out Droughts). These measures can yield an amount of water larger than the total that is drawn from the Delta today. State agencies in charge of water matters should systematically promote these practices, and *all* State agencies should model them in their own water usage. (**Water Resources Recommendations 6, 8, and 14.**)

Zooming in a bit from the statewide picture, the Delta Plan calls for all water users linked to the Delta—whether they take water from it directly, or tap the watershed—to reduce their draws. The State Water Resources Control Board should give special scrutiny to water use applications that could boost demand on the watershed. Urban and agricultural water suppliers are already required to write water management plans; these now should include "water supply reliability elements," discussing, among other things, how to deal with the cascading effects if Delta pumping were halted for as long as 3 years. (**Water Resources Recommendations 3, 4, 5, and 7.**)

The Delta Watershed and Areas Receiving Delta Water

Figure ES-1

The Plan speaks most directly to those suppliers that serve water within the Delta or pump water out of the region—including the State Water Project, the Central Valley Project, and by extension the many agricultural and urban water purveyors that are the customers of these giants. Any organization that receives water from the projects must do its share to reduce reliance on the Delta, setting specific reduction targets and actually putting measures in place.

The State Water Project is called on to write the corresponding provisions into contracts with its clients when these agreements are renewed or revised (**Water Resources Policies 1 and 2, WR Recommendation 2**).

A Better System: Storing Floods to Ride Out Droughts (and Give the Delta a Break)

The measures so far mentioned will take pressure off the Delta while actually increasing California's developed water supply. The further key to both goals is to harvest and store the water that is available from Central Valley rivers in the wettest years, at the least environmental cost. The need is heightened by the fact of climate change, which stands to make rainy years all the wetter, and droughts all the more severe.

There are few opportunities left in California to build large new dams (or to raise the height of old dams), and the options that exist are dauntingly expensive. The California Department of Water Resources and the Bureau of Reclamation have been studying the possibilities. The Delta Plan urges the agencies to wrap up these studies, so that the State can decide the fate of these proposals once and for all (**Water Resources Recommendations 13 and 14**).

Much more water storage space exists right under our feet: in groundwater basins, or aquifers.

California began its history with a vast supply of water stored naturally in underground gravel fields and free for the taking via wells. In parts of the state, including most of the southern Central Valley, this endowment has been squandered, and groundwater levels have dropped, sometimes by hundreds of feet. One of the rationales for sending water south from the Delta has been to recharge aquifers, but not enough recharging has occurred. And the State's last comprehensive assessment of its groundwater situation was published in 1980—a third of a century ago.

The Delta Plan calls for a rededication to the conservative idea of using aquifers like bank accounts: to be filled up in wet times, in order that they may be drawn from in dry. It calls on the State to do the indispensable groundwater update, on local suppliers to write plans for sustainable groundwater management, and on the State Water Resources Control Board to stand ready to intervene in seriously overdrafted areas, if good local plans are not forthcoming, leading perhaps to the court procedure called groundwater adjudication. (**Water Resources Recommendations 9, 10, 11, and 14**.)

> ***The Delta Plan calls for a rededication to the conservative idea of using aquifers like bank accounts: to be filled up in wet times, in order that they may be drawn from in dry.***

There is another tool for making the supply stretch further: the sale or trade of water between suppliers, especially in times of shortage. Existing rules governing such transfers are found cumbersome by some and insufficiently protective of water rights and the environment by others. The State Water Resources Control Board should reformulate the guidelines by mid-2016 (**Water Resources Recommendations 14 and 15**).

A Better System: Delta Conveyance

As noted, many of the state's water suppliers take their water from rivers at points upstream of the Delta. The two biggest, however—the State Water Project and the Central Valley Project—are different. Though most of the water they transport has its origin to the north, in the Sacramento River, their withdrawal points are deep in the Delta and well to the south, on the channel called Old River. Unlike most other water withdrawals, these affect the region not only by removing water but also by distorting flows.

The pumps at Byron have so much power that they essentially give the Delta a second mouth. In many channels, water runs backward at times, toward the pump intakes, not toward the sea. This situation is bad for salmon, Delta smelt, and other sensitive and legally protected species. Under the Bay Delta Conservation Plan, the Department of Water Resources and the federal Bureau of Reclamation are planning a kind of arterial bypass, segregating the water meant for the pumps at a new northern intake on the Sacramento River. The water corralled at this point would be sent to the pumps via a pair of tunnels. This arrangement is intended to alleviate the backward flows that harm fish; in conjunction with major habitat improvements and other measures, it is supposed to bring endangered species far enough back from the brink to satisfy protective laws. Many Delta residents and environmentalists, though, fear that the new system will simply allow more water to be shipped south, doing, on balance, more harm than good.

The Delta Stewardship Council is not the author of the BDCP. Its role for now is to advise and to urge timely completion (**Water Resources Recommendation 12**). Later on, though, the Council may have a decisive say. Once the proposal is complete, the Department of Fish and Wildlife must declare that it meets the standards of the Delta Reform Act, and this declaration can in turn be appealed to the Council. If the Council does not concur, certain aspects of the BDCP will lose access to State funding. If all hurdles have been cleared, on the other hand, the BDCP will take its place as a component of the Delta Plan.

...and Protecting, Restoring, and Enhancing the Delta Ecosystem...

The effort to improve the fortunes of the Delta ecosystem has two components that are vital: guaranteeing adequate flows from the rivers feeding into and through Delta channels, and creating new wetlands and other habitats in partial replacement for what has been lost. Three other components are merely very important: combating harmful exotic species, improving the management of salmon hatcheries, and protecting and improving water quality.

Toward "Natural Functional Flows"

Humans have not only reduced the total quantity of runoff through the Delta toward the ocean but also have changed its timing, decreasing the historical torrents of spring and increasing the formerly feeble flows of autumn. In a natural system that evolved with wide variation, this shift toward a steady state is itself a source of harm.

Humans have not only reduced the total quantity of runoff through the Delta toward the ocean but also have changed its timing, decreasing the historical torrents of spring and increasing the formerly feeble flows of autumn.

The minimum seaward flows to be maintained in Delta channels are set by the State Water Resources Control Board, according to season and year type (wet, above normal, below normal, dry, or critical). These required flows help fish; they also prevent saltwater intrusion. As a not-incidental side effect, the rules limit the amount of water that can be exported through the pumps.

The Water Board is now preparing to revise this flow regime, last updated in 2006. As a later step, the Water Board is to issue comparable flow standards for the major tributary rivers of the Delta. The Delta Plan recommends deadlines for these processes (mid-2014 and mid-2018). The adopted regulations will become elements of the Plan. The Delta Stewardship Council can be called upon to review any project that could affect Delta flows in the light of adopted flow criteria (**Ecosystem Restoration Policy 1, ER Recommendation 1**).

Habitat Restoration

In its primeval state, the Delta was no uniform sea of reeds but a vast mesh of habitats including tule marsh threaded with rivers and sloughs, perched lakes filled by floods and very high tides, natural levees with big trees on them, and seasonal overflow basins behind the levees. Most of this mosaic has disappeared, converted to fifty large and many small leveed islands. Evidence of what was remains in agricultural soils of uncommon quality (and fragility).

The old scene will never return, but careful habitat restoration projects can help to reverse the region's ecological decline. Biologists have spent years locating the likeliest areas for such revival. The Delta Plan incorporates the latest thinking, essentially the Conservation Strategy drafted in 2011 by the Department of Fish and Wildlife (formerly the Department of Fish and Game).

Since the heart of the Delta is now well below sea level, due to subsidence, the suitable restoration sites are mostly found near Delta margins, where the soil surface is still high enough to permit marsh plants and riparian vegetation to take root. The Plan outlines six such zones: the Yolo Bypass, the floodplain west of Sacramento into which the Sacramento River spills in wet years; the Cache Slough Complex, where the Bypass rejoins the body of the Delta; a nexus in the eastern Delta, where the Mokelumne River and the Cosumnes River add their strands to the Delta's web; a zone in the southern Delta along the San Joaquin River; a collection of small tracts at the western apex of the Delta, where it narrows to meet Suisun Bay; and finally the Suisun Marsh, fringing that bay to the north. This fresh-to-brackish water marsh, the largest wetland in California, is mostly managed by hunting clubs for seasonal waterfowl ponds, but sizeable areas should be restored to full tidal action. The existing plan for Suisun Marsh, written by the San Francisco Bay Conservation and Development Commission, is 36 years old and does not take into account, for example, probable sea level rise.

The Delta Plan calls for the habitat restorations in the Conservation Strategy to be carried out by the Department of Fish and Wildlife and by the Delta Conservancy, a body established for such purposes in 2009; and it calls for a plan update for Suisun Marsh. The Delta Stewardship Council can be appealed to, if necessary, to block development or any other intrusion that might interfere with a restoration site. (**Ecosystem Restoration Policies 2 and 3, ER Recommendations 2, 3, and 5**.)

Much of the remaining good habitat in the Delta is found in strips along the water side of levees, and the Delta Plan looks to protect and widen these green margins. When levees are rebuilt or altered, the possibility of shifting them farther away from the water should always be explored. The growth of trees along the waterline should be encouraged. However, authority over many levees lies with the U.S. Army Corps of Engineers, and the Corps requires removal of trees and shrubs, on the theory that root systems have a weakening effect. (The matter is debated.) Given the value of tall vegetation for habitat, the Delta Plan asks the Corps to exempt Delta levees from this rule, where appropriate. (**Ecosystem Restoration Policy 4 and ER Recommendation 4**.)

Exotic Species

One of the less-visible forces to buffet the Delta ecosystem is the proliferation of nonnative aquatic species—fish, crustaceans, plants, and even the microscopic floating animals of zooplankton. Some were introduced deliberately; others arrived by random routes including the discharge of bilgewater from oceangoing ships and the dumping of goldfish bowls.

New arrivals keep appearing. Some of these intruders affect the system little, but other species, notably certain aquatic plants and filter-feeding clams, transform the web of life profoundly. The Delta Plan prohibits actions that could bring in new exotics or improve conditions for exotics that are here, and endorses the measures the Department of Fish and Wildlife is already planning to take against them. (**Ecosystem Restoration Policy 5, ER Recommendation 7**.)

Among the exotics are game species introduced in the nineteenth century and well-loved by fishermen: striped, largemouth, and smallmouth bass. It has become apparent that these voracious game fish are helping to deplete salmon, Delta smelt, and other species in trouble. The Delta Plan asks the Department of Fish and Wildlife to change angling rules to permit heavier fishing and somewhat suppress the bass population (**Ecosystem Restoration Recommendation 6**).

Management of Hatchery Fish

When dams on many rivers cut off spawning grounds for salmon and steelhead trout, hatcheries were built to compensate. Now there is worry that hatchery-raised salmon, less genetically diverse than their wild cousins, may mix with and reduce the fitness of the wild strains. Various solutions are proposed, including capturing wild fish to add their eggs to hatchery stock. The Delta Plan asks the Department of Fish and Wildlife and the U.S. Fish and Wildlife Service to put these ideas and recommendations into effect (**Ecosystem Restoration Recommendations 8 and 9**).

Water Quality

Pollution from the watershed is bad for the Delta ecosystem and for water users. The Delta Plan urges the responsible agencies—the State Water Resources Control Board, the Central Valley Regional Water Quality Control Board, and the San Francisco Bay Regional Water Quality Control Board—to protect "beneficial uses" of water in the Delta and Suisun Bay. Various ongoing projects of planning, rulemaking, and construction should be brought to conclusion. All agencies should look at water quality when weighing actions covered under the Delta Plan. Special attention should be paid to pollution that might degrade habitat restoration sites. (**Water Quality Recommendations 1 through 12**.)

...In a Way that Protects and Enhances the Values of the Delta as an Evolving Place

Because of its role in greater systems—the San Francisco Estuary, the state water plumbing—the Delta is a subject of statewide debate. The conversation can seem to take place over the heads of the people who actually live in the region; and it can seem to overlook the lasting values of the place that is: its thriving agriculture, the beauty of its countryside, its cultural heritage, and its recreational bounty. The Delta Plan strives to redress this balance without promising what is probably impossible: the retention of the landscape exactly as it is today.

Honorific labels do not protect valuable assets, but they can help us recognize them. The Delta Plan asks that the Delta be declared a National Heritage Area by Congress and that Highway 160, its north-south artery, be designated a National Scenic Byway by the U.S. Department of Transportation (**Delta-as-Place Recommendations 1 and 2**).

Many Delta people fear that their concerns will be brushed aside as new water facilities and habitat restorations get under way. While deference cannot be guaranteed, the Delta Plan calls on the agencies to respect local plans in siting such projects, to minimize conflict when possible, and to buy land from willing sellers when they can (**Delta-as-Place Policy 2, DP Recommendation 4**).

The distinctive Delta landscape has been much altered by urban encroachment, often entailing higher flood risk. The Delta Protection Commission, created in 1992 and strengthened by the Delta Reform Act of 2009, oversees development in the core area called the Primary Zone: Local decisions affecting this zone can be appealed to the Commission and overturned by it. However, this authority does not extend to the peripheral Secondary Zone, where the development pressure is strongest. The Delta Plan tightens control further, steering new development to the 26,000 acres in the Peripheral Zone that are already earmarked for urbanization in local plans. Small housing developments that may occur outside these limits must meet high flood control standards (**Delta-as-Place Policy 1, Risk Reduction Policy 2**). (See Figure ES-2, Delta Communities.)

A little more bustle might actually benefit 11 historic small towns or settlements within the Delta, known as the legacy communities. Most are spaced along the Sacramento River: Freeport, Clarksburg, Hood, Courtland, Locke, Walnut Grove, Ryde, Isleton, and Rio Vista. Knightsen and Bethel Island are near the lower channel of the San Joaquin River. Planners at all levels should respect the character, and promote the vitality, of these places (**Delta-as-Place Recommendation 3**).

The Delta Protection Commission has written an Economic Sustainability Plan containing numerous ideas for the support of the region's farm economy, parks and recreation, and roads and infrastructure. The Delta Plan adapts many of these as **Delta-as-Place Recommendations 5 through 19**.

Flood Risk Reduction

In its primeval state, most of the Delta was wetland and slightly above sea level. Since levees created the modern islands and cultivation began, soils have subsided deeply. Many Delta tracts are strikingly below the level of the water in adjacent channels; rising sea level will make the differential worse. While the occasional levee break is part of Delta lore, multiple failures could bring disaster to the Delta landscape, economy, and ecosystem.

The Delta Plan urges all agencies in the Delta to plan for emergencies and to join forces in a regional response consortium, as proposed by the Delta Multi-Hazard Coordination Task Force. Every responsible party, public and private, should allocate money for flood prevention and reaction. Utilities should plan to minimize interruptions of service. The Department of Water Resources should expand its stockpiles of stone and earth for the use of all when breaches require rapid plugging. Higher levels of private flood insurance should be required, and the State should gain immunity from lawsuits related to flooding beyond its power to prevent. (**Risk Reduction Recommendations 1, 9, and 10**.)

> ***It is estimated that only about half the Delta's acreage is adequately protected. There is not enough money for all the desirable improvements, nor is there a mechanism for sharing costs among all who benefit.***

Delta Communities

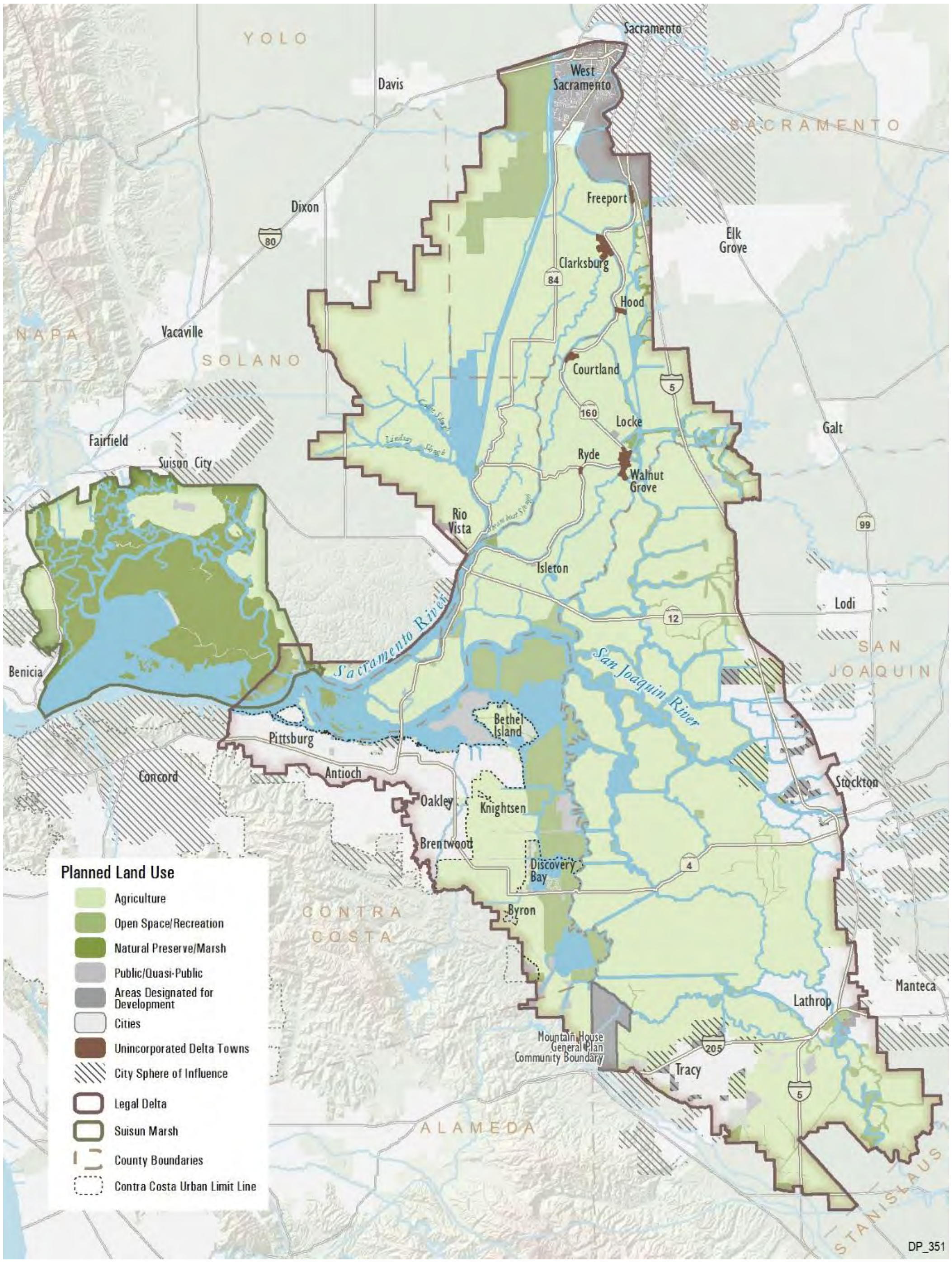

Figure ES-2 *Sources: City of Benicia 2003, Contra Costa County 2008, Contra Costa County 2010, City of Fairfield 2008, City of Lathrop 2012, City of Manteca 2012, Mountain House Community Services District 2008, City of Rio Vista 2001, SACOG 2009, City of Sacramento 2008, Sacramento County 2011, Sacramento County 2012, Sacramento County 2013, San Joaquin County 2008a, San Joaquin County 2008b, Solano County 2008a, Solano County 2008b, City of Stockton 2011a, City of Stockton 2011b, City of Suisun City 2011, City of Tracy 2011a, City of Tracy 2011b, City of West Sacramento 2010, Yolo County 2010a, Yolo County 2010b.*

There are more than 1,000 miles of Delta levees. The State is directly responsible for about one-third of the system; nearly 70 local Reclamation Districts are in charge of the rest. It is estimated that only about half the Delta's acreage is adequately protected. There is not enough money for all the desirable improvements, nor is there a mechanism for sharing costs among all who benefit. The Delta Plan calls on the Legislature to establish a locally based Delta Flood Risk Management Assessment District to raise money for combined defenses. Public and private utilities, too, should invest in defense of their facilities and lines. (**Risk Reduction Recommendations 2 and 3**.)

The State contributes massively to levee costs throughout the Delta, but on a not very systematic basis. The Legislature directed the Delta Stewardship Council to set priorities for these investments. **Risk Reduction Policy 1** offers broad principles. Urban areas come first; special attention must be paid to levees guarding roads and energy facilities. The channels through which water flows toward export pumps require protection, as does the pipeline that brings Sierra water across the Delta for the East Bay Municipal Utility District. Levees on the western islands, whose failure could bring salinity deep into the Delta, are also of high concern.

A more detailed study is to follow. Building on work being done by the Department of Water Resources, the Council will assess, island by island, the state of levees, the degree of subsidence, the extent and value of assets to be protected, and the cost of long-term defense. The result, due at the end of 2014, will be a tiered priority list for the expenditure of State levee funds (**Risk Reduction Recommendation 4**).

To take pressure off the levee system, floodwaters need room to move and to spread without causing harm (and often to the benefit of plants, birds, and fish). Two such safety valves already exist at the Yolo Bypass and the Cosumnes-Mokelumne floodplain; a third such zone is proposed for the lower San Joaquin River at Paradise Cut. The Delta Plan urges expansion of the flood relief system, and requires that present or potential overflow areas be kept free of encroachments. Levee setbacks are also encouraged. (**Risk Reduction Policies 3 and 4, RR Recommendations 5 through 8**.)

Given time, land subsidence can actually be reversed. Experimental plots show that soils can be deepened by growing tules in shallowly flooded fields, at a rate of a little over an inch a year. The tule plots also fix a lot of atmospheric carbon and thus do their bit toward slowing climate change. The Delta Plan encourages expansion of this work (**Delta-as-Place Recommendation 7**).

Finding the Way Through

When the first Spanish explorers took their boats into the Sacramento-San Joaquin River Delta, they were feeling their way. They could see the channel they were in, as far as the next bend or junction of sloughs. They had a general idea of where they were going. Between the near and the far, though, were mysteries. Which waterways connected to others, which petered out in the marshes? Where was the real way through?

Tangible marks of progress may at first be as subtle as shifting shoreline features seen from a Delta boat.

This first edition of the Delta Plan is a little like such an exploration. A short reach of channel is visible; another stretch can be assessed from local information. After that, the route is a matter of educated guesswork.

The Delta Plan can be fairly specific about steps to be taken in the next 5 years. The Delta Science Plan is already under way. The in-depth study of levees will begin by fall 2013. The Interagency Implementation Committee will meet by the end of the year. Just around the next bend, the State Water Resources Control Board will adopt its momentous new flow rules; a final decision on Delta conveyance (the Bay Delta Conservation Plan) looms beyond that.

It will not have escaped the reader how many of these measures seem rather abstract, involving studies, rule-making, the gathering of information, the refining of procedures, the testing of powers—not so much doing as planning, and even planning how to plan. This is simply the phase we are in. Tangible marks of progress may at first be as subtle as shifting shoreline features seen from a Delta boat. Here, though, are some markers to look for. We will be doing well if, in a few years' time:

- Many urban and rural water suppliers that draw on the Delta have taken real steps to reduce that reliance, with measured, reported results.
- Flows in Delta channels, controlled under new State Water Resources Control Board rules, are looking a good deal more like the historical ones.
- Several new habitat restoration projects in the Delta have moved from the planning to the construction stage.
- Subsidence reversal planting has expanded from the small pilot projects seen today.
- Measurably less acreage of Delta waters is dominated by nonnative water plants.
- Stocks of endangered fish are showing a rebound.
- Key levees have been strengthened, especially in the environs of Stockton and Sacramento.
- No further rural farmland has been lost to urbanization.

The next edition of the Delta Plan, due in 2018 or sooner, will be a little longer on specifics and a little shorter on question marks. A few more miles of the channel ahead will have come into view. New uncertainties, no doubt, will have replaced old. The captains will continue to disagree. But, just as it was in the old days, the route through the Delta will be the one way forward.

Beyond all local debates and confusions, the destination is clear. We want a Delta landscape that remains essentially itself while adapting gradually and gracefully to a future marked by climate change and sea level rise. We want a Delta ecosystem that works markedly better than today's, reflected partly in a resurgence of native fish. And we want an end to the endless wrangling about Delta flows and plumbing—a truce that can only be achieved if the entire California water system undergoes a measure of reform.

> ***In solving the "Delta problem," we will not only be doing right by a treasured land- and waterscape. We will be putting the entire state of California on a sounder development path.***

Driven by cost, environmental concern, and sheer practicality, the water world is already shifting away from reliance on distant dams and aqueducts and toward trust in conservation, local sources, and better use of groundwater storage. This change is reflected in the fact, startling to many, that California's total water consumption has not climbed in recent years; in fact, despite our increasing population, use has slightly dropped. The Delta Plan gives a push to trends already under way.

In solving the "Delta problem," we will not only be doing right by a treasured land- and waterscape. We will be putting the entire state of California on a sounder development path.

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Delta Plan Policies and Recommendations

The Delta Plan contains a set of regulatory policies that will be enforced by the Delta Stewardship Council's appellate authority and oversight. The Delta Plan also contains priority recommendations, which are nonregulatory but call out actions essential to achieving the coequal goals.

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
Chapter 2		
G P1 (23 CCR section 5002)	Detailed Findings to Establish Consistency with the Delta Plan	*(a) This policy specifies what must be addressed in a certification of consistency filed by a State or local public agency with regard to a covered action. This policy only applies after a "proposed action" has been determined by a State or local public agency to be a covered action because it is covered by one or more of the regulatory policies contained in Article 3. Inconsistency with this policy may be the basis for an appeal.* *(b) Certifications of consistency must include detailed findings that address each of the following requirements:* *(1) Covered actions, in order to be consistent with the Delta Plan, must be consistent with this regulatory policy and with each of the regulatory policies contained in Article 3 implicated by the covered action. The Delta Stewardship Council acknowledges that in some cases, based upon the nature of the covered action, full consistency with all relevant regulatory policies may not be feasible. In those cases, the agency that files the certification of consistency may nevertheless determine that the covered action is consistent with the Delta Plan because, on whole, that action is consistent with the coequal goals. That determination must include a clear identification of areas where consistency with relevant regulatory policies is not feasible, an explanation of the reasons why it is not feasible, and an explanation of how the covered action nevertheless, on whole, is consistent with the coequal goals. That determination is subject to review by the Delta Stewardship Council on appeal;* *(2) Covered actions not exempt from CEQA must include applicable feasible mitigation measures identified in the Delta Plan's Program EIR (unless the measure(s) are within the exclusive jurisdiction of an agency other than the agency that files the certification of consistency), or substitute mitigation measures that the agency that files the certification of consistency finds are equally or more effective;* *(3) As relevant to the purpose and nature of the project, all covered actions must document use of best available science;* *(4) Ecosystem restoration and water management covered actions must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management. This requirement shall be satisfied through both of the following:* *(A) An adaptive management plan that describes the approach to be taken consistent with the adaptive management framework in Appendix 1B, and* *(B) Documentation of access to adequate resources and delineated authority by the entity responsible for the implementation of the proposed adaptive management process.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		(c) A conservation measure proposed to be implemented pursuant to a natural community conservation plan or a habitat conservation plan that was: *(1) Developed by a local government in the Delta; and* *(2) Approved and permitted by the California Department of Fish and Wildlife prior to May 16, 2013* *is deemed to be consistent with sections 5005 through 5009 of this Chapter if the certification of consistency filed with regard to the conservation measure includes a statement confirming the nature of the conservation measure from the California Department of Fish and Wildlife.*
G R1	Development of a Delta Science Plan	*The Delta Stewardship Council's Delta Science Program should develop a Delta Science Plan by December 31, 2013. The Delta Science Program should work with the Interagency Ecological Program, Bay Delta Conservation Plan, California Department of Fish and Wildlife, and other agencies to develop the Delta Science Plan. To ensure that best science is used to develop the Delta Science Plan, the Delta Independent Science Board should review the draft Delta Science Plan.* *The Delta Science Plan should address the following:* ▪ *A collaborative institutional and organizational structure for conducting science in the Delta* ▪ *Data management, synthesis, scientific exchange, and communication strategies to support adaptive management and improve the accessibility of information* ▪ *Strategies for addressing uncertainty and conflicting scientific information* ▪ *The prioritization of research and balancing of the short-term immediate science needs with science that enhances comprehensive understanding of the Delta system over the long term* ▪ *Identification of existing and future needs for refining and developing numerical and simulation models along with enhancing existing Delta conceptual models (e.g., the Interagency Ecological Program (IEP) Pelagic Organism Decline (POD) and the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) models)* ▪ *An integrated approach for monitoring that incorporates existing and future monitoring efforts* ▪ *An assessment of financial needs and funding sources to support science*
Chapter 3		
WR P1 (23 CCR section 5003)	Reduce Reliance on the Delta through Improved Regional Water Self-Reliance	*(a) Water shall not be exported from, transferred through, or used in the Delta if all of the following apply:* *(1) One or more water suppliers that would receive water as a result of the export, transfer, or use have failed to adequately contribute to reduced reliance on the Delta and improved regional self-reliance consistent with all of the requirements listed in paragraph (1) of subsection (c);* *(2) That failure has significantly caused the need for the export, transfer, or use; and* *(3) The export, transfer, or use would have a significant adverse environmental impact in the Delta.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action to export water from, transfer water through, or use water in the Delta, but does not cover any such action unless one or more water suppliers would receive water as a result of the proposed action. *(c) (1) Water suppliers that have done all of the following are contributing to reduced reliance on the Delta and improved regional self-reliance and are therefore consistent with this policy:* *(A) Completed a current Urban or Agricultural Water Management Plan (Plan) which has been reviewed by the California Department of Water Resources for compliance with the applicable requirements of Water Code Division 6, Parts 2.55, 2.6, and 2.8;* *(B) Identified, evaluated, and commenced implementation, consistent with the implementation schedule set forth in the Plan, of all programs and projects included in the Plan that are locally cost effective and technically feasible which reduce reliance on the Delta; and* *(C) Included in the Plan, commencing in 2015, the expected outcome for measurable reduction in Delta reliance and improvement in regional self-reliance. The expected outcome for measurable reduction in Delta reliance and improvement in regional self-reliance shall be reported in the Plan as the reduction in the amount of water used, or in the percentage of water used, from the Delta watershed. For the purposes of reporting, water efficiency is considered a new source of water supply, consistent with Water Code section 1011(a).* *(2) Programs and projects that reduce reliance could include, but are not limited to, improvements in water use efficiency, water recycling, stormwater capture and use, advanced water technologies, conjunctive use projects, local and regional water supply and storage projects, and improved regional coordination of local and regional water supply efforts.*
WR R1	Implement Water Efficiency and Water Management Planning Laws	*All water suppliers should fully implement applicable water efficiency and water management laws, including urban water management plans (Water Code section 10610 et seq.); the 20 percent reduction in statewide urban per capita water usage by 2020 (Water Code section 10608 et seq.); agricultural water management plans (Water Code section 10608 et seq. and 10800 et seq.); and other applicable water laws, regulations, or rules.*
WR R2	Require SWP Contractors to Implement Water Efficiency and Water Management Laws	*The California Department of Water Resources should include a provision in all State Water Project contracts, contract amendments, contract renewals, and water transfer agreements that requires the implementation of all State water efficiency and water management laws, goals, and regulations, including compliance with Water Code section 85021.*
WR R3	Compliance with Reasonable and Beneficial Use	*The State Water Resources Control Board should evaluate all applications and petitions for a new water right or a new or changed point of diversion, place of use, or purpose of use that would result in new or increased long-term average use of water from the Delta watershed for consistency with the constitutional principle of reasonable and beneficial use. The State Water Resources Control Board should conduct its evaluation consistent with Water Code sections 85021, 85023, 85031, and other provisions of California law. An applicant or*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		petitioner should submit to the State Water Resources Control Board sufficient information to support findings of consistency, including, as applicable, its urban water management plan, agricultural water management plan, and environmental documents prepared pursuant to the California Environmental Quality Act.
WR R4	Expanded Water Supply Reliability Element	*Water suppliers that receive water from the Delta watershed should include an expanded water supply reliability element, starting in 2015, as part of the update of an urban water management plan, agricultural water management plan, integrated water management plan, or other plan that provides equivalent information about the supplier's planned investments in water conservation and water supply development. The expanded water supply reliability element should detail how water suppliers are reducing reliance on the Delta and improving regional self-reliance consistent with Water Code section 85201 through investments in local and regional programs and projects, and should document the expected outcome for a measurable reduction in reliance on the Delta and improvement in regional self-reliance. At a minimum, these plans should include a plan for possible interruption of water supplies for up to 36 months due to catastrophic events impacting the Delta, evaluation of the regional water balance, a climate change vulnerability assessment, and an evaluation of the extent to which the supplier's rate structure promotes and sustains efficient water use.*
WR R5	Develop Water Supply Reliability Element Guidelines	*The California Department of Water Resources, in consultation with the Delta Stewardship Council, the State Water Resources Control Board, and others, should develop and approve, by December 31, 2014, guidelines for the preparation of a water supply reliability element so that water suppliers can begin implementation of WR R4 by 2015.*
WR R6	Update Water Efficiency Goals	*The California Department of Water Resources and the State Water Resources Control Board should establish an advisory group with other State agencies and stakeholders to identify and implement measures to reduce impediments to achievement of statewide water conservation, recycled water, and stormwater goals by 2014. This group should evaluate and recommend updated goals for additional water efficiency and water resource development by 2018. Issues such as water distribution system leakage should be addressed. Evaluation should include an assessment of how regions are achieving their proportional share of these goals.*
WR R7	Revise State Grant and Loan Priorities	*The California Department of Water Resources, the State Water Resources Control Board, the California Department of Public Health, and other agencies, in consultation with the Delta Stewardship Council, should revise State grant and loan ranking criteria by December 31, 2013, to be consistent with Water Code section 85021 and to provide a priority for water suppliers that includes an expanded water supply reliability element in their adopted urban water management plans, agricultural water management plans, and/or integrated regional water management plans.*
WR R8	Demonstrate State Leadership	*All State agencies should take a leadership role in designing new and retrofitted State-owned and -leased facilities, including buildings and California Department of Transportation facilities, to increase water efficiency, use recycled water, and incorporate stormwater runoff capture and low-impact development strategies.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
WR R9	Update Bulletin 118, California's Groundwater Plan	*The California Department of Water Resources, in consultation with the Bureau of Reclamation, U.S. Geological Survey, the State Water Resources Control Board, and other agencies and stakeholders should update Bulletin 118 information using field data, California Statewide Groundwater Elevation Monitoring (CASGEM), groundwater agency reports, satellite imagery, and other best available science by December 31, 2014, so that this information can be included in the next California Water Plan Update and be available for inclusion in 2015 urban water management plans and agricultural water management plans. The Bulletin 118 update should include a systematic evaluation of major groundwater basins to determine sustainable yield and overdraft status; a projection of California's groundwater resources in 20 years if current groundwater management trends remain unchanged; anticipated impacts of climate change on surface water and groundwater resources; and recommendations for State, federal, and local actions to improve groundwater management. In addition, the Bulletin 118 update should identify groundwater basins that are in a critical condition of overdraft.*
WR R10	Implement Groundwater Management Plans in Areas that Receive Water from the Delta Watershed	*Water suppliers that receive water from the Delta watershed and that obtain a significant percentage of their long-term average water supplies from groundwater sources should develop and implement sustainable groundwater management plans that are consistent with both the required and recommended components of local groundwater management plans identified by the California Department of Water Resources Bulletin 118 (Update 2003) by December 31, 2014.*
WR R11	Recover and Manage Critically Overdrafted Groundwater Basins	*Local and regional agencies in groundwater basins that have been identified by the California Department of Water Resources as being in a critical condition of overdraft should develop and implement a sustainable groundwater management plan, consistent with both the required and recommended components of local groundwater management plans identified by the California Department of Water Resources Bulletin 118 (Update 2003), by December 31, 2014. If local or regional agencies fail to develop and implement these plans, the State Water Resources Control Board should take action to determine if the continued overuse of a groundwater basin constitutes a violation of the State's Constitution Article X, Section 2, prohibition on unreasonable use of water and whether a groundwater adjudication is necessary to prevent the destruction of or irreparable injury to the quality of the groundwater, consistent with Water Code sections 2100 and 2101.*
WR R12	Complete Bay Delta Conservation Plan	*The relevant federal, State, and local agencies should complete the Bay Delta Conservation Plan, consistent with the provisions of the Delta Reform Act, and receive required incidental take permits by December 31, 2014.*
WR R13	Complete Surface Water Storage Studies	*The California Department of Water Resources should complete surface water storage investigations of proposed off-stream surface storage projects by December 31, 2012, including an evaluation of potential additional benefits of integrating operations of new storage with proposed Delta conveyance improvements, and recommend the critical projects that need to be implemented to expand the state's surface storage.*
WR R14	Identify Near-term Opportunities for Storage, Use, and Water Transfer Projects	*The California Department of Water Resources, in coordination with the California Water Commission, Bureau of Reclamation, State Water Resources Control Board, California Department of Public Health, the Delta Stewardship Council, and other agencies and stakeholders, should conduct a survey to identify projects throughout California that could be implemented within the next 5 to 10 years to expand existing surface and groundwater storage facilities, create new storage, improve operation of existing Delta conveyance*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		facilities, and enhance opportunities for conjunctive use programs and water transfers in furtherance of the coequal goals. The California Water Commission should hold hearings and provide recommendations to the California Department of Water Resources on priority projects and funding.
WR R15	Improve Water Transfer Procedures	*The California Department of Water Resources and the State Water Resources Control Board should work with stakeholders to identify and recommend measures to reduce procedural and administrative impediments to water transfers and protect water rights and environmental resources by December 31, 2016. These recommendations should include measures to address potential issues with recurring transfers of up to 1 year in duration and improved public notification for proposed water transfers.*
WR P2 (23 CCR section 5004)	Transparency in Water Contracting	*(a) The contracting process for water from the State Water Project and/or the Central Valley Project must be done in a publicly transparent manner consistent with applicable policies of the California Department of Water Resources and the Bureau of Reclamation referenced below.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers the following:* *(1) With regard to water from the State Water Project, a proposed action to enter into or amend a water supply or water transfer contract subject to California Department of Water Resources Guidelines 03-09 and/or 03-10 (each dated July 3, 2003), which are attached as Appendix 2A; and* *(2) With regard to water from the Central Valley Project, a proposed action to enter into or amend a water supply or water transfer contract subject to section 226 of P.L. 97-293, as amended or section 3405(a)(2)(B) of the Central Valley Project Improvement Act, Title XXXIV of Public Law 102-575, as amended, which are attached as Appendix 2B, and Rules and Regulations promulgated by the Secretary of the Interior to implement these laws.*
WR R16	Supplemental Water Use Reporting	*The State Water Resources Control Board should require water rights holders submitting supplemental statements of water diversion and use or progress reports under their permits or licenses to report on the development and implementation of all water efficiency and water supply projects and on their net (consumptive) use.*
WR R17	Integrated Statewide System for Water Use Reporting	*The California Department of Water Resources, in coordination with the State Water Resources Control Board, California Department of Public Health, California Public Utilities Commission, California Energy Commission, Bureau of Reclamation, California Urban Water Conservation Council, and other stakeholders, should develop a coordinated statewide system for water use reporting. This system should incorporate recommendations for inclusion of data needed to better manage California's water resources. The system should be designed to simplify reporting; reduce the number of required reports where possible; be made available to the public online; and be integrated with the reporting requirements for the urban water management plans, agricultural water management plans, and integrated regional water management plans. Water suppliers that export water from, transfer water through, or use water in the Delta watershed should be full participants in the data base.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
WR R18	California Water Plan	*The California Department of Water Resources, in consultation with the State Water Resources Control Board, and other agencies and stakeholders, should evaluate and include in the next and all future California Water Plan updates information needed to track water supply reliability performance measures identified in the Delta Plan, including an assessment of water efficiency and new water supply development, regional water balances, improvements in regional self-reliance, reduced regional reliance on the Delta, and reliability of Delta exports, and an overall assessment of progress in achieving the coequal goals.*
WR R19	Financial Needs Assessment	*As part of the California Water Plan Update, the California Department of Water Resources should prepare an assessment of the state's water infrastructure. This should include the costs of rehabilitating/replacing existing infrastructure, an assessment of the costs of new infrastructure, and an assessment of needed resources for monitoring and adaptive management for these projects. The California Department of Water Resources should also consider a survey of agencies that may be planning small-scale projects (such as storage or conveyance) that improve water supply reliability.*
Chapter 4		
ER P1 (23 CCR section 5005)	Delta Flow Objectives	*(a) The State Water Resources Control Board's Bay Delta Water Quality Control Plan flow objectives shall be used to determine consistency with the Delta Plan. If and when the flow objectives are revised by the State Water Resources Control Board, the revised flow objectives shall be used to determine consistency with the Delta Plan.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, the policy set forth in subsection (a) covers a proposed action that could significantly affect flow in the Delta.*
ER R1	Update Delta Flow Objectives	*Development, implementation, and enforcement of new and updated flow objectives for the Delta and high-priority tributaries are key to the achievement of the coequal goals. The State Water Resources Control Board should update the Bay Delta Water Quality Control Plan objectives as follows:* *(a) By June 2, 2014, adopt and implement updated flow objectives for the Delta that are necessary to achieve the coequal goals.* *(b) By June 2, 2018, adopt, and as soon as reasonably possible, implement flow objectives for high-priority tributaries in the Delta watershed that are necessary to achieve the coequal goals.*[1] *Flow objectives could be implemented through several mechanisms including negotiation and settlement, Federal Energy Regulatory Commission relicensing, or adjudicative proceeding.*[2] *Prior to the establishment of revised flow objectives identified above, the existing Bay Delta Water Quality Control Plan objectives shall be used to determine consistency with the Delta Plan. After the flow objectives are revised, the revised objectives shall be used to determine consistency with the Delta Plan.*

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[1] SWRCB staff should work with the Council and DFW to determine priority streams. As an illustrative example, priority streams could include the Merced River, Tuolumne River, Stanislaus River, Lower San Joaquin River, Deer Creek (tributary to Sacramento River), Lower Butte Creek, Mill Creek (tributary to Sacramento River), Cosumnes River, and American River. Implementation through hearings is expected to take longer than the deadline shown here.

[2] Implementation through adjudicative proceedings or FERC relicensing is expected to take longer than the deadline shown here.

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
ER P2 (23 CCR section 5006)	Restore Habitats at Appropriate Elevations	*(a) Habitat restoration must be carried out consistent with Appendix 3, which is Section II of the Draft Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions (California Department of Fish and Wildlife 2011). The elevation map attached as Appendix 4 should be used as a guide for determining appropriate habitat restoration actions based on an area's elevation. If a proposed habitat restoration action is not consistent with Appendix 4, the proposal shall provide rationale for the deviation based on best available science.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that includes habitat restoration.*
ER P3 (23 CCR section 5007)	Protect Opportunities to Restore Habitat	*(a) Within the priority habitat restoration areas depicted in Appendix 5, significant adverse impacts to the opportunity to restore habitat as described in section 5006, must be avoided or mitigated.* *(b) Impacts referenced in subsection (a) will be deemed to be avoided or mitigated if the project is designed and implemented so that it will not preclude or otherwise interfere with the ability to restore habitat as described in section 5006.* *(c) Impacts referenced in subsection (a) shall be mitigated to a point where the impacts have no significant effect on the opportunity to restore habitat as described in section 5006. Mitigation shall be determined, in consultation with the California Department of Fish and Wildlife, considering the size of the area impacted by the covered action and the type and value of habitat that could be restored on that area, taking into account existing and proposed restoration plans, landscape attributes, the elevation map shown in Appendix 4, and other relevant information about habitat restoration opportunities of the area.* *(d) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions in the priority habitat restoration areas depicted in Appendix 5. It does not cover proposed actions outside those areas.*
ER P4 (23 CCR section 5008)	Expand Floodplains and Riparian Habitats in Levee Projects	*(a) Levee projects must evaluate and where feasible incorporate alternatives, including the use of setback levees, to increase floodplains and riparian habitats. Evaluation of setback levees in the Delta shall be required only in the following areas (shown in Appendix 8): (1) The Sacramento River between Freeport and Walnut Grove, the San Joaquin River from the Delta boundary to Mossdale, Paradise Cut, Steamboat Slough, Sutter Slough; and the North and South Forks of the Mokelumne River, and (2) Urban levee improvement projects in the cities of West Sacramento and Sacramento.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action to construct new levees or substantially rehabilitate or reconstruct existing levees.*
ER R2	Prioritize and Implement Projects that Restore Delta Habitat	*Bay Delta Conservation Plan implementers, California Department of Fish and Wildlife, California Department of Water Resources, and the Delta Conservancy should prioritize and implement habitat restoration projects in the areas shown on Figure 4-8. Habitat restoration projects should ensure connections between areas being restored and existing habitat areas and other elements of the landscape needed for the full life cycle of the species that will benefit from the restoration project.*

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		Where possible, restoration projects should also emphasize the potential for improving water quality. Restoration project proponents should consult the California Department of Public Health's Best Management Practices for Mosquito Control in California*.* ▪ ***Yolo Bypass.*** *Enhance the ability of the Yolo Bypass to flood more frequently to provide more opportunities for migrating fish, especially Chinook salmon, to use this system as a migration corridor that is rich in cover and food.* ▪ ***Cache Slough Complex.*** *Create broad nontidal, freshwater, emergent-plant-dominated wetlands that grade into tidal freshwater wetlands, and shallow subtidal and deep open-water habitats. Also, return a significant portion of the region to uplands with vernal pools and grasslands.* ▪ ***Cosumnes River–Mokelumne River confluence.*** *Allow these unregulated and minimally regulated rivers to flood over their banks during winter and spring frequently and regularly to create seasonal floodplains and riparian habitats that grade into tidal marsh and shallow subtidal habitats.* ▪ ***Lower San Joaquin River floodplain.*** *Reconnect the floodplain and restore more natural flows to stimulate food webs that support native species. Integrate habitat restoration with flood management actions, when feasible.* ▪ ***Suisun Marsh.*** *Restore significant portions of Suisun Marsh to brackish marsh with land-water interactions to support productive, complex food webs to which native species are adapted and to provide space to adapt to rising sea level action. Use information from adaptive management processes during the Suisun Marsh Habitat Management, Preservation, and Restoration Plan's implementation to guide future habitat restoration projects and to inform future tidal marsh management.* ▪ ***Western Delta/Eastern Contra Costa County.*** *Restore tidal marsh and channel margin habitat at Dutch Slough and western islands to support food webs and provide habitat for native species.*
ER R3	Complete and Implement Delta Conservancy Strategic Plan	*As part of its Strategic Plan and subsequent Implementation Plan or annual work plans, the Delta Conservancy should:* ▪ *Develop and adopt criteria for prioritization and integration of large-scale ecosystem restoration in the Delta and Suisun Marsh, with sustainability and use of best available science as foundational principles.* ▪ *Develop and adopt processes for ownership and long-term operations and management of land in the Delta and Suisun Marsh acquired for conservation or restoration.* ▪ *Develop and adopt a formal mutual agreement with the California Department of Water Resources, California Department of Fish and Wildlife, federal interests, and other State and local agencies on implementation of ecosystem restoration in the Delta and Suisun Marsh.* ▪ *Develop, in conjunction with the Wildlife Conservation Board, the California Department of Water Resources, California Department of Fish and Wildlife, Bay Delta Conservation Plan implementers, and other State and local agencies, a plan and protocol for acquiring the land necessary to achieve ecosystem restoration consistent with the coequal goals and the Ecosystem Restoration Program Conservation Strategy.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		- *Lead an effort, working with State and federal fish agencies, to investigate how to better use habitat credit agreements to provide credit for each of these steps: (1) acquisition for future restoration; (2) preservation, management, and enhancement of existing habitat; (3) restoration of habitat; and (4) monitoring and evaluation of habitat restoration projects.* - *Work with the California Department of Fish and Wildlife and the U.S. Fish and Wildlife Service to develop rules for voluntary safe harbor agreements with property owners in the Delta whose actions contribute to the recovery of listed threatened or endangered species.*
ER R4	Exempt Delta Levees from the U.S. Army Corps of Engineers' Vegetation Policy	*Considering the ecosystem value of remaining riparian and shaded riverine aquatic habitat along Delta levees, the U.S. Army Corps of Engineers should agree with the California Department of Fish and Wildlife and the California Department of Water Resources on a variance that exempts Delta levees from the U.S. Army Corps of Engineers' levee vegetation policy where appropriate.*
ER R5	Update the Suisun Marsh Protection Plan	*The San Francisco Bay Conservation and Development Commission should update the Suisun Marsh Protection Plan and relevant components of the Suisun Marsh Local Protection Program to adapt to sea level rise and ensure consistency with the Suisun Marsh Preservation Act, the Delta Reform Act, and the Delta Plan.*
ER P5 (23 CCR section 5009)	Avoid Introductions of and Habitat Improvements for Invasive Nonnative Species	*(a) The potential for new introductions of or improved habitat conditions for nonnative invasive species, striped bass, or bass must be fully considered and avoided or mitigated in a way that appropriately protects the ecosystem.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that has the reasonable probability of introducing or improving habitat conditions for nonnative invasive species.*
ER R6	Regulate Angling for Nonnative Sport Fish to Protect Native Fish	*The California Department of Fish and Wildlife should develop, for consideration by the Fish and Game Commission, proposals for new or revised fishing regulations designed to increase populations of listed fish species through reduced predation by introduced sport fish. The proposals should be based on sound science that demonstrates these management actions are likely to achieve their intended outcome and include the development of performance measures and a monitoring plan to support adaptive management.*
ER R7	Prioritize and Implement Actions to Control Nonnative Invasive Species	*The California Department of Fish and Wildlife and other appropriate agencies should prioritize and fully implement the list of "Stage 2 Actions for Nonnative Invasive Species" and accompanying text shown in Appendix J taken from the* Conservation Strategy for Restoration of the Sacramento–San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions *(DFG 2011). Implementation of the Stage 2 actions should include the development of performance measures and monitoring plans to support adaptive management.*
ER R8	Manage Hatcheries to Reduce Genetic Risk	*As required by the National Marine Fisheries Service, all hatcheries providing listed fish for release into the wild should continue to develop and implement scientifically sound Hatchery and Genetic Management Plans (HGMPs) to reduce risks to those species. The California Department of Fish and Wildlife should provide annual updates to the Delta Stewardship Council on the status of HGMPs within its jurisdiction.*

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ER R9	Implement Marking and Tagging Program	*By December 2014, the California Department of Fish and Wildlife, in cooperation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, should revise and begin implementing its program for marking and tagging hatchery salmon and steelhead to improve management of hatchery and wild stocks based on recommendations of the California Hatchery Scientific Review Group, which considered mass marking, reducing hatchery programs, and mark selective fisheries in developing its recommendations.*
Chapter 5		
DP R1	Designate the Delta as a National Heritage Area	*The Delta Protection Commission should complete its application for designation of the Delta and Suisun Marsh as a National Heritage Area, and the federal government should complete the process in a timely manner.*
DP R2	Designate State Route 160 as a National Scenic Byway	*The California Department of Transportation should seek designation of State Route 160 as a National Scenic Byway, and prepare and implement a scenic byway plan for it.*
DP P1 (23 CCR section 5010)	Locate New Urban Development Wisely	*(a) New residential, commercial, and industrial development must be limited to the following areas, as shown in Appendix 6 and Appendix 7:* *(1) Areas that city or county general plans as of May 16, 2013, designate for residential, commercial, and industrial development in cities or their spheres of influence;* *(2) Areas within Contra Costa County's 2006 voter-approved urban limit line, except no new residential, commercial, and industrial development may occur on Bethel Island unless it is consistent with the Contra Costa County general plan effective as of May 16, 2013;* *(3) Areas within the Mountain House General Plan Community Boundary in San Joaquin County; or* *(4) The unincorporated Delta towns of Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove.* *(b) Notwithstanding subsection (a), new residential, commercial, and industrial development is permitted outside the areas described in subsection (a) if it is consistent with the land uses designated in county general plans as of May 16, 2013, and is otherwise consistent with this Chapter.* *(c) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions that involve new residential, commercial, and industrial development that is not located within the areas described in subsection (a). In addition, this policy covers any such action on Bethel Island that is inconsistent with the Contra Costa County general plan effective as of May 16, 2013. This policy does not cover commercial recreational visitor-serving uses or facilities for processing of local crops or that provide essential services to local farms, which are otherwise consistent with this Chapter.* *(d) This policy is not intended in any way to alter the concurrent authority of the Delta Protection Commission to separately regulate development in the Delta's Primary Zone.*

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DP P2 (23 CCR section 5011)	Respect Local Land Use When Siting Water or Flood Facilities or Restoring Habitats	(a) *Water management facilities, ecosystem restoration, and flood management infrastructure must be sited to avoid or reduce conflicts with existing uses or those uses described or depicted in city and county general plans for their jurisdictions or spheres of influence when feasible, considering comments from local agencies and the Delta Protection Commission. Plans for ecosystem restoration must consider sites on existing public lands, when feasible and consistent with a project's purpose, before privately owned sites are purchased. Measures to mitigate conflicts with adjacent uses may include, but are not limited to, buffers to prevent adverse effects on adjacent farmland.* (b) *For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions that involve the siting of water management facilities, ecosystem restoration, and flood management infrastructure.*
DP R3	Plan for the Vitality and Preservation of Legacy Communities	*Local governments, in cooperation with the Delta Protection Commission and Delta Conservancy, should prepare plans for each community that emphasize its distinctive character, encourage historic preservation, identify opportunities to encourage tourism, serve surrounding lands, or develop other appropriate uses, and reduce flood risks.*
DP R4	Buy Rights of Way from Willing Sellers When Feasible	*Agencies acquiring land for water management facilities, ecosystem restoration, and flood management infrastructure should purchase from willing sellers, when feasible, including consideration of whether lands suitable for proposed projects are available at fair prices.*
DP R5	Provide Adequate Infrastructure	*The California Department of Transportation, local agencies, and utilities should plan infrastructure, such as roads and highways, to meet needs of development consistent with sustainable community strategies, local plans, the Delta Protection Commission's* Land Use and Resource Management Plan for the Primary Zone of the Delta, *and the Delta Plan.*
DP R6	Plan for State Highways	*The Delta Stewardship Council, as part of the prioritization of State levee investments called for in Water Code section 85306, should consult with the California Department of Transportation as provided in Water Code section 85307(c) to consider the effects of flood hazards and sea level rise on State highways in the Delta.*
DP R7	Subsidence Reduction and Reversal	*The following actions should be considered by the appropriate State agencies to address subsidence reversal:* ▪ *State agencies should not renew or enter into agricultural leases on Delta or Suisun Marsh islands if the actions of the lessee promote or contribute to subsidence on the leased land, unless the lessee participates in subsidence reversal or reduction programs.* ▪ *State agencies currently conducting subsidence reversal projects in the Delta on State-owned lands should investigate options for scaling up these projects if they have been deemed successful. The California Department of Water Resources should develop a plan, including funding needs, for increasing the extent of their subsidence reversal and carbon sequestration projects to 5,000 acres by January 1, 2017.* ▪ *The Delta Stewardship Council, in conjunction with the California Air Resources Board (CARB) and the Delta Conservancy, should investigate the opportunity for the development of a carbon market whereby Delta farmers could receive credit for carbon sequestration by reducing subsidence and growing native marsh and wetland plants. This investigation should include the potential for developing offset protocols applicable to these types of plants for subsequent adoption by the CARB.*

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DP R8	Promote Value-added Crop Processing	*Local governments and economic development organizations, in cooperation with the Delta Protection Commission and the Delta Conservancy, should encourage value-added processing of Delta crops in appropriate locations.*
DP R9	Encourage Agritourism	*Local governments and economic development organizations, in cooperation with the Delta Protection Commission and the Delta Conservancy, should support growth in agritourism, particularly in and around legacy communities. Local plans should support agritourism where appropriate.*
DP R10	Encourage Wildlife-friendly Farming	*The California Department of Fish and Wildlife, the Delta Conservancy, and other ecosystem restoration agencies should encourage habitat enhancement and wildlife-friendly farming systems on agricultural lands to benefit both the environment and agriculture.*
DP R11	Provide New and Protect Existing Recreation Opportunities	*Water management and ecosystem restoration agencies should provide recreation opportunities, including visitor-serving business opportunities, at new facilities and habitat areas whenever feasible; and existing recreation facilities should be protected, using California State Parks'* Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh *and Delta Protection Commission's* Economic Sustainability Plan for the Sacramento-San Joaquin Delta *as guides.*
DP R12	Encourage Partnerships to Support Recreation and Tourism	*The Delta Protection Commission and Delta Conservancy should encourage partnerships between other State and local agencies, and local landowners and business people to expand recreation, including boating, promote tourism, and minimize adverse impacts to nonrecreational landowners.*
DP R13	Expand State Recreation Areas	*California State Parks should add or improve recreation facilities in the Delta in cooperation with other agencies. As funds become available, it should fully reopen Brannan Island State Recreation Area, complete the park at Delta Meadows-Locke Boarding House, and consider adding new State parks at Barker Slough, Elkhorn Basin, the Wright-Elmwood Tract, and south Delta.*
DP R14	Enhance Nature-based Recreation	*The California Department of Fish and Wildlife, in cooperation with other public agencies, should collaborate with nonprofits, private landowners, and business partners to expand wildlife viewing, angling, and hunting opportunities.*
DP R15	Promote Boating Safety	*The California Department of Boating and Waterways should coordinate with the U.S. Coast Guard and State and local agencies on an updated marine patrol strategy for the region.*
DP R16	Encourage Recreation on Public Lands	*Public agencies owning land should increase opportunities, where feasible, for bank fishing, hunting, levee-top trails, and environmental education.*
DP R17	Enhance Opportunities for Visitor-serving Businesses	*Cities, counties, and other local and State agencies should work together to protect and enhance visitor-serving businesses by planning for recreation uses and facilities in the Delta, providing infrastructure to support recreation and tourism, and identifying settings for private visitor-serving development and services.*
DP R18	Support the Ports of Stockton and West Sacramento	*The ports of Stockton and West Sacramento should encourage maintenance and carefully designed and sited development of port facilities.*

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DP R19	Plan for Delta Energy Facilities	*The California Energy Commission and California Public Utilities Commission should cooperate with the Delta Stewardship Council as described in Water Code section 85307(d) to identify actions that should be incorporated in the Delta Plan by 2017 to address the needs of Delta energy development, storage, and distribution.*
Chapter 6		
WQ R1	Protect Beneficial Uses	*Water quality in the Delta should be maintained at a level that supports, enhances, and protects beneficial uses identified in the applicable State Water Resources Control Board or regional water quality control board water quality control plans.*
WQ R2	Identify Covered Action Impacts	*Covered actions should identify any significant impacts to water quality.*
WQ R3	Special Water Quality Protections for the Delta	*The State Water Resources Control Board or regional water quality control board should evaluate and, if appropriate, propose special water quality protections for priority habitat restoration areas identified in recommendation ER R2 or other areas of the Delta where new or increased discharges of pollutants could adversely impact beneficial uses.*
WQ R4	Complete Central Valley Drinking Water Policy	*The Central Valley Regional Water Quality Control Board should complete the Central Valley Drinking Water Policy by July 2013.*
WQ R5	Complete North Bay Aqueduct Alternative Intake Project	*The California Department of Water Resources should complete the North Bay Aqueduct Alternate Intake Project Environmental Impact Report by December 31, 2012, and begin construction as soon as possible thereafter.*
WQ R6	Protect Groundwater Beneficial Uses	*The State Water Resources Control Board should complete development of a Strategic Workplan for protection of groundwater beneficial uses, including groundwater use for drinking water, by December 31, 2012.*
WQ R7	Participation in CV-SALTS	*The State Water Resources Control Board and Central Valley Regional Water Quality Control Board should consider requiring participation by all relevant water users that are supplied water from the Delta or the Delta watershed or discharge wastewater to the Delta or the Delta watershed to participate in the Central Valley Salinity Alternatives for Long-Term Sustainability Program.*
WQ R8	Completion of Regulatory Processes, Research, and Monitoring for Water Quality Improvement	*The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards are currently engaged in regulatory processes, research, and monitoring essential to improving water quality in the Delta. In order to achieve the coequal goals, it is essential that these ongoing efforts be completed and, if possible, accelerated, and that the Legislature and Governor devote sufficient funding to make this possible. The Delta Stewardship Council specifically recommends that:* ▪ *The State Water Resources Control Board should complete development of the proposed policy for nutrients for inland surface waters of the State of California by January 1, 2014.* ▪ *The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards should prepare and begin implementation of a study plan for the development of objectives for nutrients in the Delta and Suisun Marsh by January 1, 2014. Studies needed for development of Delta and Suisun Marsh nutrient objectives should be completed by January 1, 2016. The water boards should*

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		adopt and begin implementation of nutrient objectives, either narrative or numeric, where appropriate, for the Delta and Suisun Marsh by January 1, 2018. ▪ *The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should complete the Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for diazinon and chlorpyrifos by January 1, 2013.* ▪ *The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should prioritize and accelerate the completion of the Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for pyrethroids by January 1, 2016.* ▪ *The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards have completed Total Maximum Daily Load and Basin Plan Amendments for methylmercury, and efforts to support their implementation should be coordinated. Parties identified as responsible for current methylmercury loads or proponents of projects that may increase methylmercury loading in the Delta or Suisun Marsh should participate in control studies or implement site-specific study plans that evaluate practices to minimize methylmercury discharges. The Central Valley Regional Water Quality Control Board should review these control studies by December 31, 2018, and determine control measures for implementation starting in 2020.*
WQ R9	Implement Delta Regional Monitoring Program	*The State Water Resources Control Board and Regional Water Quality Control Boards should work collaboratively with the California Department of Water Resources, California Department of Fish and Wildlife, and other agencies and entities that monitor water quality in the Delta to develop and implement a Delta Regional Monitoring Program that will be responsible for coordinating monitoring efforts so Delta conditions can be efficiently assessed and reported on a regular basis.*
WQ R10	Evaluate Wastewater Recycling, Reuse, or Treatment	*The Central Valley Regional Water Quality Control Board, consistent with existing water quality control plan policies and water rights law, should require responsible entities that discharge wastewater treatment plant effluent or urban runoff to Delta waters to evaluate whether all or a portion of the discharge can be recycled, otherwise used, or treated in order to reduce contaminant loads to the Delta by January 1, 2014.*
WQ R11	Manage Dissolved Oxygen in Stockton Ship Channel	*The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should complete Phase 2 of the Total Maximum Daily Load and Basin Plan Amendment for dissolved oxygen in the Stockton Deep Water Ship Channel by January 1, 2015.*
WQ R12	Manage Dissolved Oxygen in Suisun Marsh	*The State Water Resources Control Board and the San Francisco Bay Regional Water Quality Control Board should complete the Total Maximum Daily Load and Basin Plan Amendment for dissolved oxygen in Suisun Marsh wetlands by January 1, 2014.*

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Chapter 7		
RR R1	Implement Emergency Preparedness and Response	*The following actions should be taken by January 1, 2014, to promote effective emergency preparedness and response in the Delta:* ▪ *Responsible local, State, and federal agencies with emergency response authority should consider and implement the recommendations of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force (Water Code section 12994.5). Such actions should support the development of a regional response system for the Delta.* ▪ *In consultation with local agencies, the California Department of Water Resources should expand its emergency stockpiles to make them regional in nature and usable by a larger number of agencies in accordance with California Department of Water Resources' plans and procedures. The California Department of Water Resources, as a part of this plan, should evaluate the potential of creating stored material sites by "over-reinforcing" west Delta levees.* ▪ *Local levee-maintaining agencies should consider developing their own emergency action plans, and stockpiling rock and flood-fighting materials.* ▪ *State and local agencies and regulated utilities that own and/or operate infrastructure in the Delta should prepare coordinated emergency response plans to protect the infrastructure from long-term outages resulting from failures of the Delta levees. The emergency procedures should consider methods that also would protect Delta land use and ecosystem.*
RR R2	Finance Local Flood Management Activities	*The Legislature should create a Delta Flood Risk Management Assessment District with fee assessment authority (including over State infrastructure) to provide adequate flood control protection and emergency response for the regional benefit of all beneficiaries, including landowners, infrastructure owners, and other entities that benefit from the maintenance and improvement of Delta levees, such as water users who rely on the levees to protect water quality.* *This district should be authorized to:* ▪ *Identify and assess all beneficiaries of Delta flood protection facilities.* ▪ *Develop, fund, and implement a regional plan of flood management for both project and nonproject levees of the Delta, including the maintenance and improvement of levees, in cooperation with the existing reclamation districts, cities, counties, and owners of infrastructure and other interests protected by the levees.* ▪ *Require local levee-maintaining agencies to conduct annual levee inspections per the California Department of Water Resources subventions program guidelines, and update levee improvement plans every 5 years.* ▪ *Participate in the collection of data and information necessary for the prioritization of State investments in Delta levees consistent with RR P1.* ▪ *Notify residents and landowners of flood risk, personal safety information, and available systems for obtaining emergency information before and during a disaster on an annual basis.* ▪ *Potentially implement the recommendations of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force (Water Code section 12994.5) in conjunction with local, State, and federal agencies, and maintain the resulting regional response system*

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		and components and procedures on behalf of SEMS jurisdictions (reclamation district, city, county, and State) that would jointly implement the regional system in response to a disaster event. ▪ *Identify and assess critical water supply corridor levee operations, maintenance, and improvements.*
RR R3	Fund Actions to Protect Infrastructure from Flooding and Other Natural Disasters	▪ *The California Public Utilities Commission should immediately commence formal hearings to impose a reasonable fee for flood and disaster prevention on regulated privately owned utilities with facilities located in the Delta. Publicly owned utilities should also be encouraged to develop similar fees. The California Public Utilities Commission, in consultation with the Delta Stewardship Council, the California Department of Water Resources, and the Delta Protection Commission, should allocate these funds among State and local emergency response and flood protection entities in the Delta. If a new regional flood management agency is established by law, a portion of the local share would be allocated to that agency.* ▪ *The California Public Utilities Commission should direct all regulated public utilities in their jurisdiction to immediately take steps to protect their facilities in the Delta from the consequences of a catastrophic failure of levees in the Delta, to minimize the impact on the State's economy.* ▪ *The Governor, by Executive Order, should direct State agencies with projects or infrastructure in the Delta to set aside a reasonable amount of funding to pay for flood protection and disaster prevention. The local share of these funds should be allocated as described above.*
RR P1 (23 CCR section 5012)	Prioritization of State Investments in Delta Levees and Risk Reduction	*(a) Prior to the completion and adoption of the updated priorities developed pursuant to Water Code section 85306, the interim priorities listed below shall, where applicable and to the extent permitted by law, guide discretionary State investments in Delta flood risk management. Key priorities for interim funding include emergency preparedness, response, and recovery as described in paragraph (1), as well as Delta levees funding as described in paragraph (2).* *(1) Delta Emergency Preparedness, Response, and Recovery: Develop and implement appropriate emergency preparedness, response, and recovery strategies, including those developed by the Delta Multi-Hazard Task Force pursuant to Water Code section 12994.5.* *(2) Delta Levees Funding: The priorities shown in the following table are meant to guide budget and funding allocation strategies for levee improvements. The goals for funding priorities are all important, and it is expected that over time, the California Department of Water Resources must balance achievement of those goals. Except on islands planned for ecosystem restoration, improvement of nonproject Delta levees to the Hazard Mitigation Plan (HMP) standard may be funded without justification of the benefits. Improvements to a standard above HMP, such as that set by the U.S. Army Corps of Engineers under Public Law 84-99, may be funded as befits the benefits to be provided, consistent with the California Department of Water Resources' current practices and any future adopted investment strategy.*

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Priorities for State Investment in Delta Integrated Flood Management

Categories of Benefit Analysis

<table>
<tr><th>Goals</th><th>Localized Flood Protection</th><th>Levee Network</th><th>Ecosystem Conservation</th></tr>
<tr><td>1</td><td>Protect existing urban and adjacent urbanizing areas by providing 200-year flood protection.</td><td>Protect water quality and water supply conveyance in the Delta, especially levees that protect freshwater aqueducts and the primary channels that carry fresh water through the Delta.</td><td>Protect existing and provide for a net increase in channel-margin habitat.</td></tr>
<tr><td>2</td><td>Protect small communities and critical infrastructure of statewide importance (located outside of urban areas).</td><td>Protect floodwater conveyance in and through the Delta to a level consistent with the State Plan of Flood Control for project levees.</td><td>Protect existing and provide for net enhancement of floodplain habitat.</td></tr>
<tr><td>3</td><td>Protect agriculture and local working landscapes.</td><td>Protect cultural, historic, aesthetic, and recreational resources (Delta as Place).</td><td>Protect existing and provide for net enhancement of wetlands.</td></tr>
</table>

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that involves discretionary State investments in Delta flood risk management, including levee operations, maintenance, and improvements. Nothing in this policy establishes or otherwise changes existing levee standards.

</td></tr>
<tr><td>RR R4</td><td>Actions for the Prioritization of State Investments in Delta Levees</td><td>

The Delta Stewardship Council, in consultation with the California Department of Water Resources, the Central Valley Flood Protection Board, the Delta Protection Commission, local agencies, and the California Water Commission, should develop funding priorities for State investments in Delta levees by January 1, 2015. These priorities shall be consistent with the provisions of the Delta Reform Act in promoting effective, prioritized strategic State investments in levee operations, maintenance, and improvements in the Delta for both levees that are a part of the State Plan of Flood Control and nonproject levees. Upon completion, these priorities shall be considered for incorporation into the Delta Plan.

The priorities should identify guiding principles, constraints, recommended cost share allocations, and strategic considerations to guide Delta flood risk reduction investments,

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		supported by, at a minimum, the following actions to be conducted by the California Department of Water Resources, consistent with available funding:
		■ *An assessment of existing Delta levee conditions. This should include the development of a Delta levee conditions map based on sound data inputs, including, but not limited to:*
		  ■ *Geometric levee assessment*
		  ■ *Flow and updated stage-frequency analysis*
		■ *An island-by-island economics-based risk analysis. This analysis should consider, but not be limited to, values related to protecting:*
		  ■ *Island residents/life safety*
		  ■ *Property*
		  ■ *Value of Delta islands' economic output, including agriculture*
		  ■ *State water supply*
		  ■ *Critical local, State, federal, and private infrastructure, including aqueducts, state highways, electricity transmission lines, gas/petroleum pipelines, gas fields, railroads, and deep water shipping channels*
		  ■ *Delta water quality*
		  ■ *Existing ecosystem values and ecosystem restoration opportunities*
		  ■ *Recreation*
		  ■ *Systemwide integrity*
		■ *An ongoing assessment of Delta levee conditions. This should include a process for updating Delta levee assessment information on a routine basis.*
		This methodology should provide the basis for the prioritization of State investments in Delta levees. It should include, but not be limited to, the public reporting of the following items:
		■ *Tiered ranking of Delta islands, based on economics-based risk analysis values*
		■ *Delta levee conditions status report, including a levee conditions map*
		■ *Inventory of Delta infrastructure assets*

RR P2 (23 CCR section 5013)	Require Flood Protection for Residential Development in Rural Areas	*(a) New residential development of five or more parcels shall be protected through flood-proofing to a level 12 inches above the 100-year base flood elevation, plus sufficient additional elevation to protect against a 55-inch rise in sea level at the Golden Gate, unless the development is located within:* *(1) Areas that city or county general plans, as of May 16, 2013, designate for development in cities or their spheres of influence;* *(2) Areas within Contra Costa County's 2006 voter-approved urban limit line, except Bethel Island;* *(3) Areas within the Mountain House General Plan Community Boundary in San Joaquin County; or* *(4) The unincorporated Delta towns of Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove, as shown in Appendix 7.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that involves new residential development of five or more parcels that is not located within the areas described in subsection (a).*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
RR P3 (23 CCR section 5014)	Protect Floodways	*(a) No encroachment shall be allowed or constructed in a floodway, unless it can be demonstrated by appropriate analysis that the encroachment will not unduly impede the free flow of water in the floodway or jeopardize public safety.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that would encroach in a floodway that is not either a designated floodway or regulated stream.*
RR P4 (23 CCR section 5015)	Floodplain Protection	*(a) No encroachment shall be allowed or constructed in any of the following floodplains unless it can be demonstrated by appropriate analysis that the encroachment will not have a significant adverse impact on floodplain values and functions:* *(1) The Yolo Bypass within the Delta;* *(2) The Cosumnes River-Mokelumne River Confluence, as defined by the North Delta Flood Control and Ecosystem Restoration Project (McCormack-Williamson), or as modified in the future by the California Department of Water Resources or the U.S. Army Corps of Engineers (California Department of Water Resources 2010); and* *(3) The Lower San Joaquin River Floodplain Bypass area, located on the Lower San Joaquin River upstream of Stockton immediately southwest of Paradise Cut on lands both upstream and downstream of the Interstate 5 crossing. This area is described in the Lower San Joaquin River Floodplain Bypass Proposal, submitted to the California Department of Water Resources by the partnership of the South Delta Water Agency, the River Islands Development Company, Reclamation District 2062, San Joaquin Resource Conservation District, American Rivers, the American Lands Conservancy, and the Natural Resources Defense Council, March 2011. This area may be modified in the future through the completion of this project.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that would encroach in any of the floodplain areas described in subsection (a).* *(c) This policy is not intended to exempt any activities in any of the areas described in subsection (a) from applicable regulations and requirements of the Central Valley Flood Protection Board.*
RR R5	Fund and Implement San Joaquin River Flood Bypass	*The Legislature should fund the California Department of Water Resources and the Central Valley Flood Protection Board to evaluate and implement a bypass and floodway on the San Joaquin River near Paradise Cut that would reduce flood stage on the mainstem San Joaquin River adjacent to the urban and urbanizing communities of Stockton, Lathrop, and Manteca in accordance with Water Code section 9613(c).*
RR R6	Continue Delta Dredging Studies	*The current efforts to maintain navigable waters in the Sacramento River Deep Water Ship Channel and Stockton Deep Water Ship Channel, led by the U.S. Army Corps of Engineers and described in the Delta Dredged Sediment Long-Term Management Strategy (USACE 2007, Appendix K), should be continued in a manner that supports the Delta Plan and the coequal goals. Appropriate dredging throughout other areas in the Delta for maintenance purposes, or that would increase flood conveyance and provide potential material for levee maintenance or subsidence reversal should be implemented in a manner that supports the Delta Plan and coequal goals. Coordinated use of dredged material in levee improvement, subsidence reversal, or wetland restoration is encouraged.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
RR R7	Designate Additional Floodways	*The Central Valley Flood Protection Board should evaluate whether additional areas both within and upstream of the Delta should be designated as floodways. These efforts should consider the anticipated effects of climate change in its evaluation of these areas.*
RR R8	Develop Setback Levee Criteria	*The California Department of Water Resources, in conjunction with the Central Valley Flood Protection Board, the California Department of Fish and Wildlife, and the Delta Conservancy, should develop criteria to define locations for future setback levees in the Delta and Delta watershed.*
RR R9	Require Flood Insurance	*The Legislature should require an adequate level of flood insurance for residences, businesses, and industries in floodprone areas.*
RR R10	Limit State Liability	*The Legislature should consider statutory and/or constitutional changes that would address the State's potential flood liability, including giving State agencies the same level of immunity with regard to flood liability as federal agencies have under federal law.*
Chapter 8		
FP R1	Conduct Current Spending Inventory	*An inventory of current State and federal spending on programs and projects that do or may achieve the coequal goals will be conducted. Data sources to be used include the CALFED cross-cut budget, State bond balance reports, and the annual State budget, among others. Consideration will be given to selecting an independent agency (which could include a non governmental organization) to conduct the inventory.*
FP R2	Develop Delta Plan Cost Assessment	*Costs will be assigned to the projects and programs proposed in the Delta Plan (Chapters 2 through 7) and sources of funding will be identified.*
FP R3	Identify Funding Gaps	*Current State and federal funding gaps will be identified that are determined to hinder progress toward meeting the coequal goals.*

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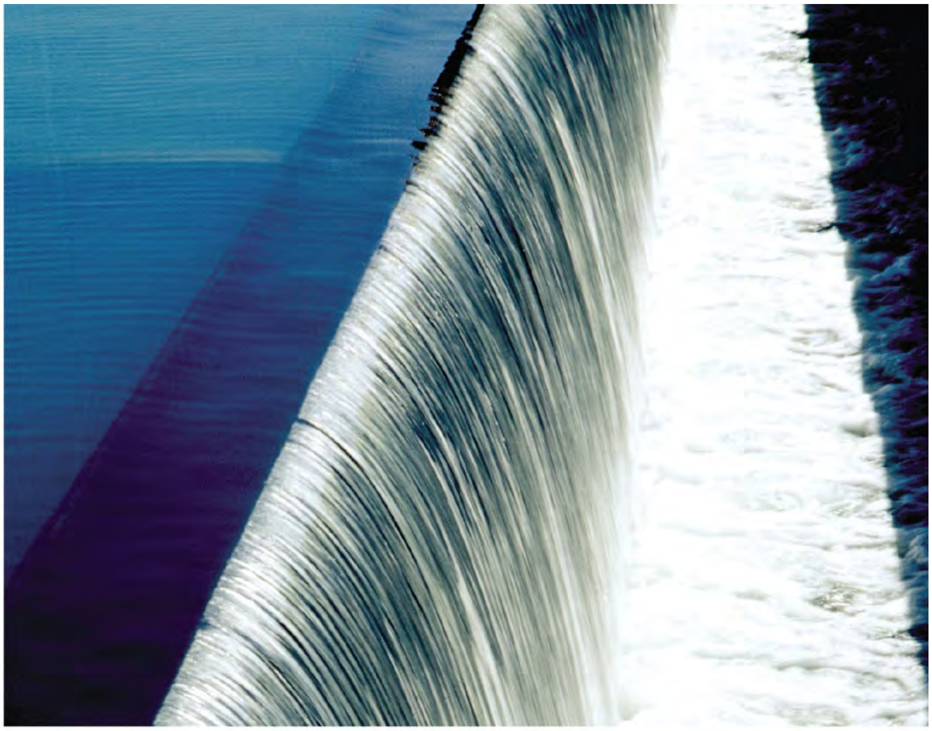
CHAPTER 1

Introduction



ABOUT THIS CHAPTER

This chapter offers historical and current contextual information about the uses and conflicts that besiege the Sacramento-San Joaquin Delta (Delta). The reader will come to understand how and why the West Coast's largest estuary has evolved from a huge tidal marsh to the maze of islands and channels it is today – shaped over more than a century and a half by the effects of hydraulic mining, flood control, agricultural and urban development, and its placement as the "hub" of California's major water systems.

The chapter then delves into the realities of decades of stand-offs among the key interests in the Delta and resulting years of relative inaction, leading finally to the bipartisan movement that created the Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act or Act) and its mandate to develop a long-term sustainable management plan for the Delta. The chapter concludes with an overarching explanation of how this Delta Plan (or Plan) will bring about a fundamental and positive sustainability and reformation of this immense natural resource.

CHAPTER 1

Introduction

Throughout the past 160 years, the delta formed by California's two largest rivers, the Sacramento and the San Joaquin, has been a gateway to many of the state's collective hopes and dreams. Once the pathway to the Gold Country, it is today a critical component of the state's water supply infrastructure, a source of sustenance for farmers and fishermen, and home to half a million people and a vast array of fish, birds, and wildlife.

The Sacramento-San Joaquin Delta and Suisun Marsh are referred to throughout this Plan collectively as "the Delta," unless otherwise specified (see Figure 1-1).[1] Once a great marsh, the Delta now is a network of channels and sunken "islands" that cover—together with Suisun Marsh—about 1,300 square miles. Laid over those islands and channels is the infrastructure of a twenty-first century economy: water supply conduits; major arteries of the state's electrical grid; natural gas fields, storage facilities, and pipelines; highways and railways; and shipping channels, all surrounded by an increasingly urban landscape. Water from the vast Delta watershed, spanning over 45,000 square miles (30 million acres), fuels both local economies and those in export areas hundreds of miles away (see Figure 1-2).

Today the Delta is many things to many people, and is universally regarded in "crisis" because people have not yet been able to find balance in the tradeoffs among competing demands for the Delta's resources. Tradeoffs and integration define the Delta dilemma: water conveyance facilities that built strong urban and agricultural economies threaten ecosystem health. Water that is beneficial for fish is alive with plankton and organic material, but sources of drinking water are best in as pure a form as possible. The pollutants of upstream urban and agricultural uses cause problems for downstream fish and water diverters alike. The same ocean-going ships that opened the Central Valley to world trade also introduced nonnative species that alter the Delta ecosystem. High water flows that historically improved habitat and a diverse food web come with the threat of lost homes, flooded farmland, and disaster for Delta residents and the California economy.

Conceived decades ago, a series of water projects has engineered the Delta estuary over time to perform as a water conveyance system, moving water stored upstream to users throughout the state who hold State of California (State) or federal water contracts. This system relies on dredged channels, which at times run counter to natural flow directions as the result of export pumping that occurs in the south Delta. For a number of years, and currently at the publishing time of this Plan, State and federal agencies are exploring options to reconfigure the manner in which the Delta is used to convey water in a way that lessens ecosystem impacts and improves water supply reliability. At this time, the Delta Plan does not make recommendations regarding Delta conveyance (see Appendix A).

As a result of imperfect tradeoffs, key species are endangered or threatened, the amount of water that can be exported from the Delta is determined not just by the state's variable precipitation and storage but also by court order to protect endangered species, and geologists and engineers continue to worry that the Delta itself is one of the greatest flood risks in the West.

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[1] The Sacramento-San Joaquin Delta is defined in Water Code section 12220, and Suisun Marsh means the area defined in Public Resources Code section 29101 and protected by Division 19 (commencing with section 29000).

The evolution of the Delta has come in fits and starts, driven by individual initiative, governmental incentive, and crisis. John Hart, writing for *Bay-Nature*, puts it this way:

> *The History of the modern Delta belies the image of the region as a static landscape. Reclamation was a battle with many setbacks, almost given up for lost in the 1870s. In the 1880s the 'crisis' was the clogging of channels by hydraulic mining debris. In the 1920s, salinity was on the march. A brief calm at midcentury gave way to the ever-spiraling tension over water exports and ecosystem decline. The Delta seems always to have been in crisis, under intensive study, and at the intersection of hostile interests.*

Governmental institutions have reacted to each crisis predictably, often treating individual problems rather than taking a systemwide approach. Over the years, dozens of agencies, task forces, and working groups have been created in a series of sometimes overlapping efforts to find the right combination of leadership and collaboration—incentives and regulation—to provide clean, reliable water; protect our environment; and reduce the risk of flooding.

After decades of conflict and unsuccessful efforts to comprehensively address the many problems and challenges of the Delta, the California Legislature (or Legislature), water agencies, and environmental groups throughout the state united in an unprecedented manner in 2009 to pass a series of water-related measures, including the Delta Reform Act.

The Delta Reform Act created the Delta Stewardship Council (Council) with a primary responsibility to develop and implement a legally enforceable, long-term management plan for the Delta. The Legislature required the Delta Plan to advance the coequal goals of protecting and enhancing the Delta ecosystem and providing for a more reliable water supply for California, and to do so in a manner that protects and enhances the Delta as an evolving place.

This Delta Plan is intended to be a foundational document that prioritizes actions and strategies in support of key objectives such as the State's requirement to reduce reliance on the Delta to meet future water supply needs. It also restricts actions that may cause harm; serves as a guidebook for all plans, projects, and programs that affect the Delta; and calls for further investigation and focused study of specific issues.

Successful implementation of the Delta Plan depends not only on the Council, but also on coordinated actions by other government agencies—federal, State, and local—and by the stakeholders to whom these agencies are responsible. To be effective, decision making in a dynamic context such as the Delta must be flexible and have the capacity to change policies and practices in response to what is learned over time. Through this Delta Plan, the Council details an interagency structure for decision making that fosters communication among scientists; local, State, and federal decision makers; and stakeholders. Future Plan iterations will build on successes as well as lessons learned in order to achieve the coequal goals.

The Delta and California's Water Supply

The story of California's annual water supply is one of great variability in amount, timing, and distribution, and of the human desire to impose certainty and order. Rain and snow fall mostly in the northern and eastern portions of the state, but most Californians live along the coast and in the south. Most of the state's precipitation occurs in only 5 to 15 days, and that rain and snowfall result in an annual supply that is ample in average years, too little in dry ones, and too much in wet years (see Figure 1-3).

The Sacramento-San Joaquin Delta and Suisun Marsh

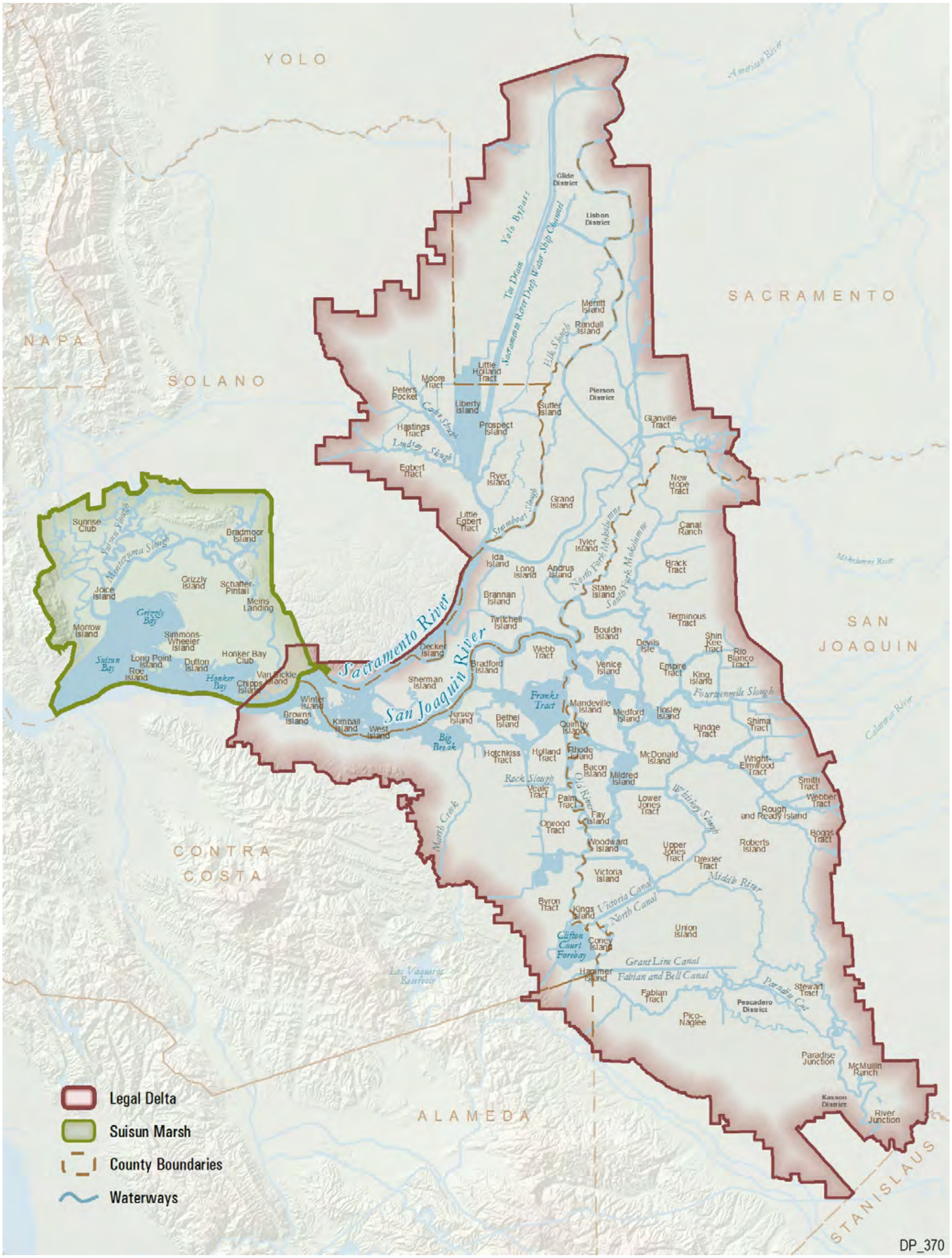

Figure 1-1 *Source: DWR 2011a*

The Delta Watershed and Areas Receiving Delta Water

Figure 1-2

To meet water demand, Californians over the past 160 years have built a vast array of reservoirs, canals, pipelines, and tunnels, all in an effort to capture water when it was available, store it for when it was not, and to move it to the people when and where they wanted it.

As residents in both Northern and Southern California feared they would outgrow their local supplies, they turned to the vast Delta watershed for relief. The river systems flowing into the Delta drain about 40 percent of the land in California and carry about half of the state's total annual runoff.

And so, at the turn of the twentieth century, San Francisco tapped the Tuolumne River, diverting water through an aqueduct that bypasses the San Joaquin River and Delta. Shortly thereafter, Oakland and the eastern San Francisco Bay Area tapped the Mokelumne River, diverting water through a pipeline across the Delta. Later, construction of the federal Central Valley Project (CVP) and the State Water Project (SWP) resulted in additional diversions directly from the Delta for the Bay Area, Central Valley, and Southern California.

California's Variable Precipitation

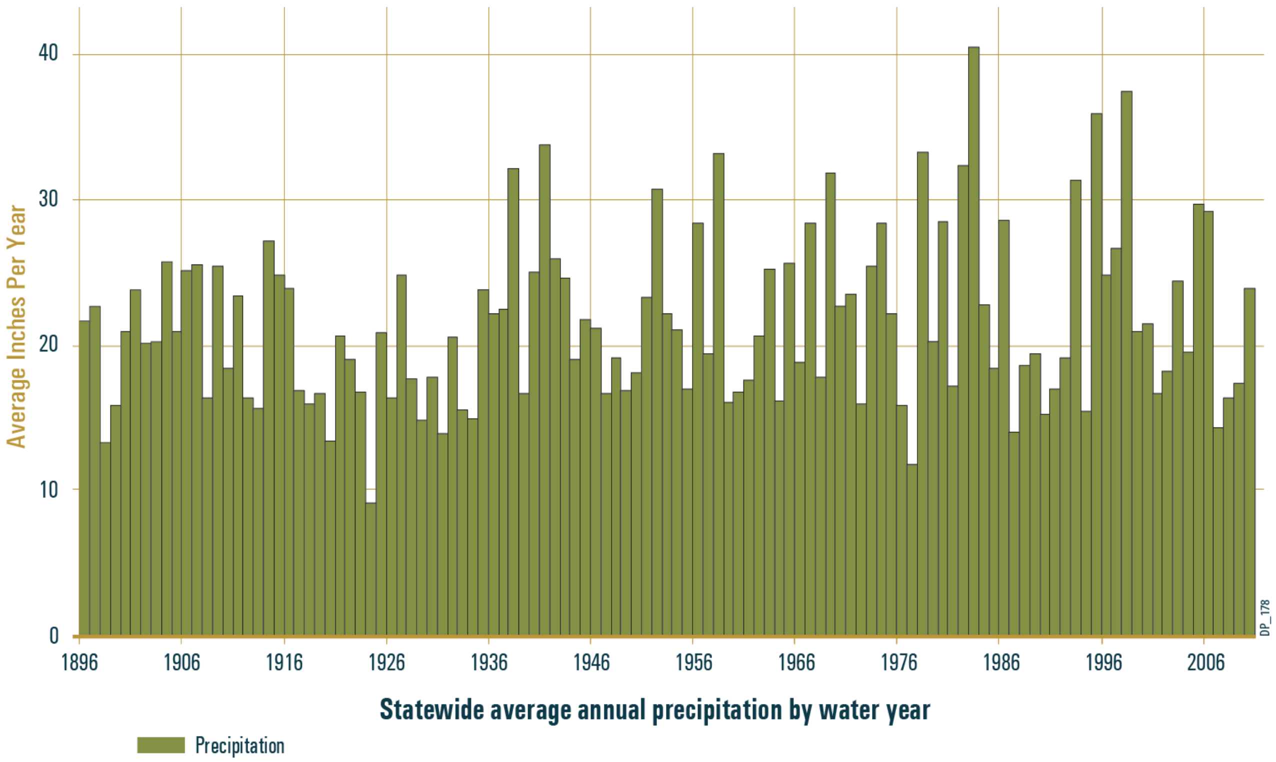

Figure 1-3 The unpredictability of the state's rainfall and its history of multiyear droughts make the management of water to reliably meet environmental and human uses extremely challenging. Yearly precipitation was calculated from the average of 95 stations located across California. Data were collected by Jim Goodridge, former State climatologist.

Source: Western Regional Climate Center 2011

Today, some two-thirds of the state's population (approximately 27 million people) depend on water from the Delta watershed for some portion of their water supply, as do more than 3 million acres of irrigated farmland that grow crops for in-state, national, and international distribution. That said, water exported through the Delta represents approximately 8 percent of the state's annual average water supply. Local and regional water resources, including surface diversions, groundwater, local and out-of-state imports, and water reuse, meet the remaining 84 percent.

Who uses all that water, how it is used, how much returns to the rivers and streams for downstream users, and in what quality, is less than certain on a statewide basis. Data for actual water use and water quality suffer from significant gaps, which may affect the ability of California's water managers to make timely and better-informed decisions. Since 1914, the State Water Resources Control Board (SWRCB) has issued permits to post-1914 appropriative-right water diverters in the Delta, but actual annual diversion amounts are not thoroughly measured or reported. Owners and operators of nearly one-third of irrigated lands in the Delta watershed do not participate in programs to meet water quality standards, and their compliance with State law is unclear.

Although groundwater and surface water are often interconnected, the SWRCB has limited authority to regulate groundwater. Groundwater is sustainably managed in some areas of the state through either adjudication or special districts, but other areas suffer from unsustainable overdraft and require improved management efforts. Attempts to correct this overdraft often put more pressure on water supplies from the Delta, demonstrating once again the interconnectedness of California's water systems.

The Delta and Its Ecosystem

Although much of the debate over the Delta has centered on events in the last 50 years, the roots of its problems run much deeper. A Delta that for millennia had been a land and waterscape of dynamic floodplain and tidal marshland, rich in flora and fauna, was changed forever by passage of the federal Swamp Land Act of 1850 and similar State legislation in 1861, which provided incentives for the "reclamation" of "nuisance" swampland to reduce threats of vector-borne disease and to gain productive land for farming. Within the Delta, seasonally and tidally flooded land impeding agricultural development led to land reclamation and channelization, and subsequent habitat loss. More than a century ago, with little or no engineering analyses and limited construction tools, Delta residents began to build an intricate levee system to channel water and dry out land, which converted hundreds of thousands of acres of seasonally and tidally flooded wetlands into fertile agricultural fields. As a result of continued land use change and urbanization, 95 percent of the historical tidal marsh in the Delta has been lost. Further detail regarding the historical Delta landscape is provided in Chapter 4.

Hydraulic gold mining, which reached its peak in the 1860s, sent tons of mercury-laden debris down toward the Delta, clogging channels and streams, and leading to devastating floods. Corrective actions—dredging and new levee construction—resulted in the loss of 90 percent of the Central Valley's riparian habitat (Katibah 1984). This massive-scale destruction has had lasting consequences for ecosystem health and, in turn, declining ecosystem health has had direct consequences for water supply operations.

The Hetch Hetchy and Mokelumne aqueducts diverted water (as they do currently) before it reached the Delta, and water use upstream increased considerably during the mid- and late 1900s. Construction of the CVP and SWP in the 1940s and 1960s, respectively, introduced new pressures on the Delta. Indeed, it is unusual to use an estuary—normally where fresh and salt water mix according to variable tidal and tributary flows—as a conveyance system for large amounts of fresh water to meet seasonal user demands.

The resulting configuration today causes river channels at times to run backward; and some fish, lacking clear migration corridors and/or migration cues, end up in dead-end channels or, worse yet, “salvaged” at the export pumps. Conflict between these competing uses was soon apparent and continues to plague water policy today.

Fish species have changed over time in response to changing habitat and flows, and from introductions both planned and accidental. Among the first introductions, in 1879, were two eastern game fish—striped bass and American shad. Today, striped bass, which are voracious predators, both support a major sport fishery and are blamed by some for the decline of smelt and salmon. Among the accidental tourists who came to stay are Asian clams, voracious eaters who can deplete the water of nutrients for native species. Of the more than 50 species of fish in the Delta today, more than half, including the most successful, are nonnative.

In addition, growing agricultural production in the Central Valley has resulted in increased runoff of pesticides and fertilizer flowing to the Delta. Runoff and wastewater discharges from increasing upstream urbanization have altered Delta water quality and, thus, its ecosystem. Increased commercial and recreational boat traffic in the Delta, as well as other causes, have introduced many nonnative species that have altered the Delta ecosystem.

The Delta as a Unique and Evolving Place

The Delta is a unique place distinguished by geography, legacy communities, a rural and agricultural setting, vibrant natural resources, and a mix of economic activities. Much has changed over the past 160 years; and although some may desire to maintain a static picture of the Delta as it is today, the past, as well as emerging science, predict constant change.

Once a marshland that was the drain of the vast Central Valley watershed, the Delta changed dramatically following the discovery of gold on the American River in 1848. Suddenly, large numbers of prospectors and service providers were beating a pathway through the Delta to the foothills and, at the peak of the rush, more than 300 steamboats plied the waters between San Francisco and Sacramento. Twenty-one years later, completion of the transcontinental railroad in 1869 freed a huge workforce, many of whom found alternative work dredging Delta channels and building levees.

Communities developed to support river traffic to and from the gold country, and later to transport agricultural products from the newly productive farmland reclaimed from the Delta marshes. The advent of the automobile resulted in a flurry of ferry construction and bridge building in the 1920s; by the 1930s, cars and trucks were replacing steamships for transportation and commercial shipping. The Stockton Deepwater Ship Channel was completed in 1933, opening a direct connection from the San Joaquin Valley to the world, and 30 years later, the Sacramento Deepwater Ship Channel did the same for the Sacramento Valley. Not coincidentally, these channels also opened the Delta to a host of exotic invasive species that hitched rides on the bottoms and in the ballast of oceangoing freighters.

Central Valley Chinook salmon have long been a critically important part of California’s fishing industry, passing through the Delta on their way from and to spawning grounds in upstream rivers and streams. Between 1900 and 1950, the fall run numbered more than a million fish returning annually to the Sacramento and San Joaquin river systems. Drought and changing Delta and ocean conditions, however, reduced those numbers to only 66,000 in 2008, resulting in a closure of the salmon fisheries off California and restrictions that lingered into 2010, devastating fishing economies (DFG 2009).

Dredging opened many of the Delta channels for sport fishing, recreational boating, and commercial enterprise. Today there are more than 100 marinas and waterside resorts, RV parks, grocery stores, and dockside restaurants; and house boating remains popular. The Delta is dotted with numerous public parks and fishing sites as well.

The Delta now is a major producer of corn, alfalfa, pasture, and tomatoes; and wine grapes are growing in prominence. Residents and visitors alike celebrate the Delta's agricultural heritage with the Asparagus Festival in Stockton and the Courtland Pear Fair.

Today, although still largely rural, the Delta is crisscrossed by interstate electric transmission lines, natural gas pipelines, and interstate roads and railroads; and it faces increasing pressure—at least on its periphery—for additional housing development. Those elements, combined with the increasing certainty of sea level rise and changing climate patterns, mean continual change for the Delta.

The Delta Problem

In California, sustainable management of the Delta is an exceedingly complex topic fraught with longstanding conflicts and challenges. The Delta and Suisun Marsh ecosystem is the largest estuary on the West Coast and a critical stopping point on the Pacific flyway. The estuary extends westward to the Golden Gate and southward to San Jose. Delta water also flushes southern San Francisco Bay. It is also the hub of the state's major water supply systems. But the Delta today is failing to balance the tradeoffs inherent in these functions, as well as to provide a place to live, work, and play for residents and visitors alike.

Today the Delta is relied upon for many services and, as a result, is not meeting the demands of farmers and urban water users who want assurances of supply and, in some cases, more water. Nor does the Delta adequately serve the needs of fish and wildlife—some threatened or endangered species' numbers remain perilously low. And the Delta itself remains inherently floodprone.

Fish Declines. In late 2004, scientists noted that several fish species in the upper San Francisco estuary (delta smelt, young striped bass, longfin smelt, and threadfin shad) had remained unusually low since 2001. Although the numbers had historically fluctuated, this steep and lasting dropoff signaled an ecological crisis. Scientists acknowledged many causes such as invasive and predatory species, upstream agricultural and urban runoff, and diminished Delta habitat. The export pumps of the SWP and CVP were culpable as well, and restrictions ensued.

Water Exports Cut. These regulatory and court-ordered restrictions on State and federal pumping, in combination with the 2007–2009 drought, significantly reduced exported water deliveries to SWP and CVP contractors. As a result, some San Joaquin Valley farmers pumped groundwater from already overtapped aquifers, fallowed fields, and, in some cases, plowed under permanent crops. The national economic recession, combined with reduced water deliveries, hit the San Joaquin Valley hard. Although the plight of farmers captured much media attention, the salmon fishery was shut down in 2008 and was restricted in 2009–2010, causing economic hardship for the commercial and recreational fishing industries. Urban water managers in the Bay Area and Southern California drew down storage and increased conservation efforts until the rains and snows of 2011 saved the day.

DELTA BY THE NUMBERS

- The 45,600-square-mile Delta watershed provides all or a portion of surface water or groundwater supplies to more than 27 million California residents.
- Approximately 8 percent of the state's water supply is exported from the Delta (DWR 2009).
- The Delta and Suisun Marsh support more than 55 fish species and more than 750 plant and wildlife species. Of these, approximately 100 wildlife species, 140 plant species, and 13 taxonomic units of fish are considered special-status species and are afforded some form of legal or regulatory protection (CNDDB 2010, USFWS 2010, CNPS 2010).
- The Delta and Suisun Marsh are home to more than one-half million residents living in dozens of communities, including portions of 12 incorporated cities such as Stockton and Sacramento, and support more than 146,000 jobs (DPC 2010).
- Approximately 57 percent of the Delta and Suisun Marsh—more than 480,000 acres of agricultural land—currently supports a highly productive agricultural industry that is valued at hundreds of millions of dollars annually (DWR 2007a, DWR 2007b, DOC 2008, DPC 2010).
- The Delta and Suisun Marsh levees and lands support interstate and state highways and railroad tracks that support intrastate and interstate traffic, more than 500 miles of major electrical transmission lines, 60 substations, and more than 400 miles of major natural gas pipelines that provide energy throughout Northern California, as well as critical pipelines that carry transportation fuels to airports and other fuel depots throughout the San Francisco Bay Area and Sacramento (DPC 2010, DWR 2009).
- The Delta and Suisun Marsh have more than 1,335 miles of levees that protect more than 800,000 acres of land and play a role in the water supplies conveyed through the Delta.
- The Delta experiences more than 12 million visitor days annually from recreational boaters (DPC 2012).* Fishing, hunting, birdwatching, and camping draw even more visitors to the area.

* The *Sacramento–San Joaquin Delta Boating Needs Assessment* (2000-2020) estimated 6.4 million annual boating-related visitor days and 2.13 million boating trips to the Delta in 2000 (DBW 2002).

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Lawsuits. Over the years, improved understanding about water quality needs and environmental protection in the Delta launched an era of complex regulation that today governs SWP and CVP water supply operations. Litigation over a host of issues related to the CVP and SWP has created a recent spate of water management actions guided by courtroom decisions. Incomplete understanding about how water project operations, pollution, invasive species, and other factors affect native Delta fish species has resulted in a regulatory scheme affecting water supplies that is characterized by uncertainty. Changing rules to curtail pumping and increase Delta outflow have compounded water supply uncertainty for agencies that use water conveyed through the Delta, particularly in drier years when ecosystem conflicts are most pronounced. Some of those agencies have contributed to the uncertainty by becoming increasingly reliant on Delta exports that were intended to be supplemental supplies, but in some cases are now relied upon as core water supplies.

Flood Threats. Adding to the complexity of these problems is the increasing volatility of Delta water supplies as a consequence of climate change, including more rain and less snow, earlier snowmelt, and higher winter and lower spring-summer runoff patterns. The potential for catastrophic levee failure in the Delta and the risk to residents and infrastructure alike posed by floods, sea level rise, earthquakes, and land subsidence is real, growing, and has outpaced the State's ability to manage and fund risk-reduction measures.

Pursuit of Balance. Finding the right balance of these competing needs and demands on the Delta has bedeviled California policy makers for decades. The media and the political system tend to focus on water supply shortages, droughts, flood risk, and the decline of fisheries. Although notable and consequential, these events are all symptoms of a greater resource problem. Not unlike other policy areas, when it comes to natural resource issues, California has long attempted to manage symptoms rather than treat core problems.

Governance and the Delta Reform Act of 2009

California has a history of addressing each problem with yet another project and/or program, each generally left to find its own way among all others already set in motion or completed. Today, more than 200 federal, State, regional, and local agencies have responsibility for some aspect of the Delta. As each agency focuses on its specific mission, cooperation, collaboration, and cohesiveness have at times been elusive.

Although the seeds were sown in governmental decisions throughout the early twentieth century, California's water "wars" came to a head during the years 1987 through 1992, when a 6-year drought in California slowed water deliveries, water quality deteriorated, and two fish species unique to the Delta—the delta smelt and winter-run Chinook salmon—were pushed to the brink of extinction. During these 6 drought years, average runoff to the state's two largest rivers dipped dramatically: 44 percent into the Sacramento River and 53 percent into the San Joaquin.

State and federal officials tried, often in conflict with each other, to deal with issues of water quality, protection of Delta fisheries, and water impacts on the state's urban and agricultural water users. In the early 1990s, endangered species listings by federal fish agencies imposed export restrictions on water users. SWRCB efforts to address aquatic resource degradation under State water laws ground to a halt after the governor complained about excessive federal interference under both the Endangered Species Act and the Clean Water Act. In 1991, the U.S. Environmental Protection Agency (USEPA) formally disapproved the SWRCB water quality control plan; and in 1992, Congress passed the Central Valley Project Improvement Act (CVPIA), which reallocated a significant portion of federal (CVP) water supplies to environmental purposes. Virtually every action taken by a State or federal agency during this period ended up in court.

Amid this chaos of competing interests and regulations, the cornerstone for future cooperation was laid when three long-time adversarial interests—environmentalists, agriculture, and urban water users—agreed to work together to find common ground. Four federal agencies—the USEPA, Bureau of Reclamation, National Marine Fisheries Service, and U.S. Fish and Wildlife Service—began collaboration on Delta issues and became known as "Club Fed." After being on the losing side of a 5-year-long State-federal tug of war over water quality standards, the State and federal administrations negotiated updated water quality standards and, in 1995, created the CALFED Bay-Delta Program.

After 5 years of negotiations and planning, the CALFED agencies completed an ambitious 30-year plan and record of decision heavily dependent on goodwill, generous State and federal funding, and Delta conditions remaining generally as they had in the immediate past. Instead, goodwill and funding evaporated in the face of fiscal crisis, scientists learned more about looming effects of climate change and emerging stressors on the Delta, and competing interests turned back to the courts to force one viewpoint or the other.

While CALFED attempted to bring a holistic focus, it was criticized for not having authority to hold individual agencies and projects accountable for interrelationships and progress and—toward the end of its first 7 years (Stage 1, 2000 through 2008)—for not being focused enough on the Delta. And yet the inescapable truth remains: actions that affect the Delta's ecosystem and its ability to provide a reliable amount of water for export are inextricably linked. The Delta Vision Task Force, created by then-Governor Arnold Schwarzenegger in 2006 to point the path forward from CALFED, reinforced the need for integration and linkage in both its 2008 *Vision for the Delta* and its *Strategic Plan*.

IS MORE GOVERNANCE REFORM NEEDED?

Senate Bill X7 1 (SBX7 1), which included the Delta Reform Act, enacted the most significant governance reform related to water and the Delta since the mid-twentieth century. Two new bodies were formed, the Sacramento-San Joaquin Delta Conservancy and the Council; the Delta Protection Commission was reorganized; and a new Delta Watermaster position was created at the SWRCB. However, some argue that governance change should not stop there.

In recent years, two nonpartisan and independent entities have proposed new water and Delta governance models, with the State's Little Hoover Commission (LHC) releasing reports in 2005 and 2010, and the Public Policy Institute of California (PPIC) releasing reports in 2007 and 2011.* Their conclusions are summarized here.

Little Hoover Commission: LHC is an independent state oversight agency established in 1962. It has a mission to identify and spur government reform in various policy areas, and has confronted the topic of water governance multiple times. In August 2010, LHC proposed dramatic restructuring of Delta and water governance in its report *Managing for Change: Modernizing California's Water Governance* (www.lhc.ca.gov).

Public Policy Institute of California: Established in 1994, the mission of PPIC is to inform and improve public policy in California through independent, objective, nonpartisan research. In 2011, PPIC released *Managing California's Water: From Conflict to Resolution* (Hanak et al. 2011), which focused more on thematic reforms building on current practices such as increasing urban water conservation and streamlining water transfers (www.ppic.org).

Although PPIC and LHC would remake water governance differently, both proposals have considerable thematic overlap:

- California lacks a system to adequately incorporate the needs of public trust resources with water supply management and planning.
- California lacks a centralized leadership structure to set statewide policy goals and manage inevitable conflicts.
- The institutional separation of water rights planning, administration, and enforcement responsibilities from water supply management complicates policy making.
- Insufficient incentives exist to promote regional cooperation and local consistency with State policy directions.
- There is concern that the demands of California Department of Water Resources' role in managing the SWP conflicts with its overall statewide water planning responsibilities.

This Delta Plan recommends governance reform related to regional Delta participation in flood management activities. As part of its role in coordinating overall efforts in the Delta, the Council will hold hearings and recommend additional governance reform to the Legislature.

** LHC 2005, LHC 2010, Lund et al. 2007, Hanak et al. 2011*

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The recommendations from the Delta Vision Task Force, along with general understanding and support from a wide variety of competing interest groups, allowed the Legislature, in 2009, to craft a package of bills that would, for the first time, begin to define those linkages in law and require accountability for implementation. In addition to the Delta Reform Act, the package included measures that set ambitious water conservation policy (20 percent reduction in statewide urban per capita water use by 2020), ensure better groundwater monitoring, and provide for increased enforcement to prevent illegal water diversions. It also included a bond measure that would help fund implementation of various parts of the package, and local and regional water supply and ecosystem projects.

The fifth bill in the package was Senate Bill X7 1 (SBX7 1), which included the Delta Reform Act. With its passage, California embarked upon a new era in Delta governance with creation of the Council, and established as overarching State policy coequal goals of a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. Through its hybrid approach—both regulatory and collaborative—the Council now has the task of facilitating coordination across a broad range of entities to achieve the State's water policy objectives.

The Delta Reform Act includes an important caveat: while past Delta efforts focused almost exclusively on water supply reliability or ecosystem protection, the Delta Reform Act requires that the coequal goals be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

In addition, the Delta Reform Act recognized the need to change the way the Delta is viewed, asking not what can be taken, but instead what can be given back. Thus, the Legislature established that the policy of the State is to reduce reliance on the Delta in meeting future water supply needs through a statewide strategy of investing in improved regional supplies, conservation, and water use efficiency. The Delta Reform Act specifies that each region depending on water from the Delta watershed shall improve its regional self-reliance for water through investment in water use efficiency, water recycling, advanced water technologies, local and regional water supply projects, and improved regional coordination of local and regional water supply efforts.

Finally, in a distinct departure from CALFED and the status quo of disparate agencies struggling to tackle complex modern resource problems, the Council was established with the authority and responsibility to develop a legally enforceable Delta Plan, and to coordinate and collaborate across the myriad governmental agencies that have responsibility for some aspect of the Delta. The Council also was charged with ensuring that actions by State and local agencies in the Delta are consistent with the Delta Plan, and adequately incorporate the best available science and adaptive management principles.

The Delta Plan

The foundation of the Delta Reform Act is the adoption of the coequal goals and direction to the Council to develop an enforceable Delta Plan to further those goals. Figure 1-4 shows the primary area covered by the Delta Plan, including features and uses referred to in policies and recommendations. Accordingly, the Council presents a Delta Plan that is practical, foundational, integrated, and adaptive:

- **Practical:** The Delta Plan builds on years of planning efforts and incorporates actions, recommendations, and strategies developed by other entities—governmental and nongovernmental—that have already invested countless hours on Delta issues and have specialized expertise.
- **Foundational:** The Delta Plan addresses intertwined challenges and establishes foundational actions for Delta management throughout this century. It lays the groundwork for near-term actions for improvement and focuses on the immediate avoidance of further harm or increased risk to the Delta. The Delta Plan shines a spotlight on urgently needed Delta habitat projects and the significant potential for local and regional water supply development. Similarly, the Delta Plan seeks to immediately halt practices known to be detrimental to the sustainability of the Delta's many functions and services.
- **Integrated:** The Delta Plan establishes an open and accountable governance mechanism for coordinating actions across agency jurisdictions and statutory objectives.

The Delta Plan

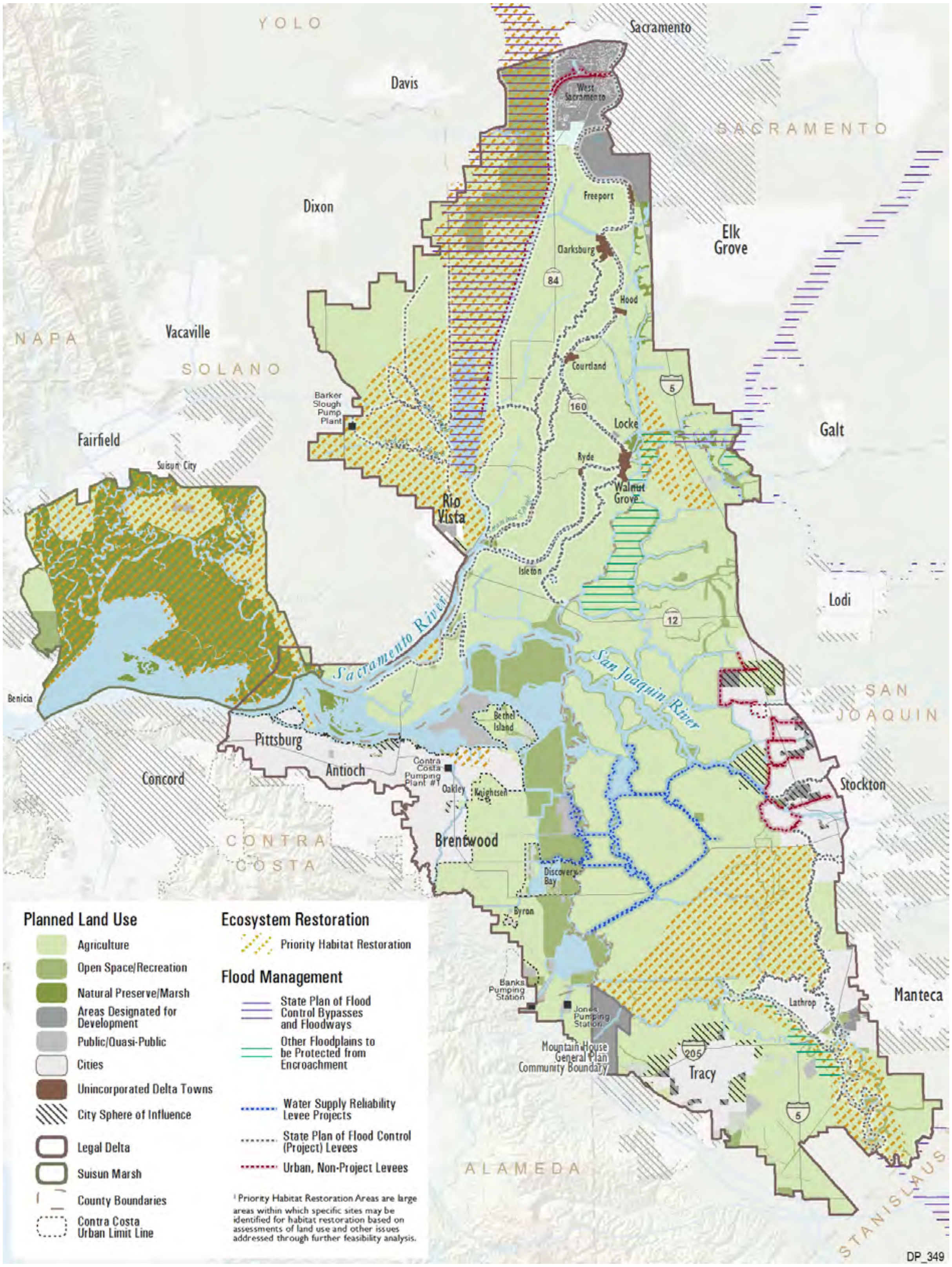

Figure 1-4 The map shows land uses designated by city and county general plans. Within cities' spheres of influences (SOIs), the map shows land use designations proposed in city general plans, where available. In cases where cities have not proposed land uses within their SOIs, the map shows land uses designated by county general plans.

Sources: City of Benicia 2003, Contra Costa County 2008, Contra Costa County 2010, DWR 2011b, DWR 2011c, DWR 2011d, City of Fairfield 2008, Jones & Stokes 2007, City of Lathrop 2012, City of Manteca 2012, Mountain House Community Services District 2008, City of Rio Vista 2001, SACOG 2009, City of Sacramento 2008, Sacramento County 2011, Sacramento County 2013, Sacramento County 2013, San Joaquin County 2008a, San Joaquin County 2008b, Solano County 2008a, Solano County 2008b, South Delta Levee Protection and Channel Maintenance Authority 2011, City of Stockton 2011a, City of Stockton 2011b, City of Suisun City 2011, City of Tracy 2011, City of Stockton 2011b, City of West Sacramento 2010, Yolo County 2010a, Yolo County 2010b.

- **Adaptable:** The Delta Plan sets direction through policies and recommendations and can incorporate other plans and new information as it becomes available. Informed by science and consistent monitoring, portions of the Delta Plan that do not adequately meet or make progress toward stated goals over time will be refined or revised. The Delta Plan will be updated at least every 5 years, and likely sooner, given the major changes facing the Delta under the Bay Delta Conservation Plan (BDCP) and the Council's commitment to Delta levee prioritization.

It is inevitable that the Delta Plan will generate controversy. This Delta Plan integrates existing State and federal laws and policies and ongoing programs, and is informed by the best available science to chart a course to further the coequal goals. The Council is one of many agencies with an interest in the Delta, and it was not granted unlimited authority over actions related to water supply and the environment. Specific and targeted authority and actions, however, were included by the Delta Reform Act; these form the basis for the Delta Plan's enforceable policies and nonenforceable recommendations.

The Delta Plan's policies and recommendations are based on the following imperatives:

- **Act now.** We have been studying the problems of California's water supply and the declining Delta ecosystem for decades. While all parties agree the *status quo* is not acceptable, failure to take action only prolongs a worsening *status quo*. Near-term actions must move forward while the long-term conveyance, storage, and ecosystem solutions are being decided over the next 5, 10, and 15 years. Waiting is NOT an option. We must continue to invest in the Delta ecosystem and in the improvement of California's water supplies and water use efficiency.
- **Success depends on integrated approaches and awareness of tradeoffs.** Tradeoffs are inherent in managing a supply for multiple benefits. Water exports out of the Delta can harm the ecosystem unless carefully managed. Protecting the Delta as a place means focusing development in urban areas to reduce effects on agricultural land, and risk to people, property, and state interests. Multiple stressors affect the ecosystem in ways that are not yet fully understood and which may be impossible to completely control. The most effective actions will depend upon the coordinated actions of multiple actors.
- **Improve water supply reliability.** Fundamentally, water supply reliability means that California must better match its demands for and use of water to the available supply. Everyone in California must conserve water and must increase their efforts to do so. New surface and groundwater storage is necessary to manage the timing of water for people and for fish. Done right, additional storage can make efficient water management possible and better allow for water use that is wildlife friendly. Improved Delta conveyance, including successful completion of the BDCP, is essential; and it should be done as soon as possible.
- **Commit to Delta ecosystem restoration.** We must preserve land in the Delta for future habitat restoration, and we must immediately begin restoration efforts on long-studied priority areas. In the Delta, the conflict between the way we move water and the health of native species must be resolved. A successfully permitted BDCP is key to that, including water quality objectives updated by the SWRCB for beneficial uses including the Delta's ecosystem. Without adequate water flow (the right mix of timing and amount), we cannot expect fisheries to recover, no matter how well we deal with the range of other stressors.
- **Preserve Delta as a place.** The Delta serves many demands, but we must preserve and protect a unique sense of place distinguished by geography, legacy communities, a rural and agricultural setting, vibrant natural resources, and a mix of economic and recreational activities.

What the Delta Plan Will Achieve

The Delta Plan seeks to further the coequal goals and their inherent objectives in the face of dramatically changing conditions. The Delta of 2100 likely will be very different from the Delta of today (see Table 1-1 for examples of anticipated changes). Some of the changes will be intentional or predictable, and others will be unintended and surprising. Changes are likely or expected to result from population growth, climate change and sea level rise, land subsidence, and earthquakes—most beyond human ability or willingness to control. Human-made changes in land use and water use are also expected to continue.

All of this will involve tradeoffs between competing—in some cases, mutually exclusive—values, goals, and objectives. The Delta Plan seeks to ensure that these decisions are made in a timely and open manner, and based on best available information and science as a predictor of the future. The law requires that the Delta Plan be updated every 5 years, and each update is intended to build on an evolving base of knowledge, directing near- and mid-term actions, and preserving and protecting longer-term opportunities as yet unknown.

Summary of Anticipated Changes Affecting the Delta by 2050 and 2100

TABLE 1-1

Anticipated Change	Change Predicted by 2050	Change Predicted by 2100
Population of California[a]	Increase from 37.2 million in 2010 to 51 million	Continued increase in population
San Francisco Bay/East Bay Area earthquake affecting Delta by 2032[b]	63% probability of at least one magnitude 6.7 or greater earthquake	
Probability of island flooding from high water, relative to 2005 conditions[c]	In range of 200% increase (medium risk scenario)	In range of 450% increase (medium risk scenario)
Increased weather variability, including longer-term droughts[d]	Models and analyses of tree rings and other evidence back to the year 800 suggest greater variability and long periods of drought, especially for the Colorado River Basin, a current source of some water to California.	
Sea level rise, relative to 2000[e]	14 inches	55 to 65 inches
Snow pack, relative to 1956–2000 average of 15 MAF[f]	Reduction of 25% (4.5 MAF) to 40% (6 MAF)	Continued reduction expected

a California Department of Finance 2012

b 2007 Working Group on California Earthquake Probabilities 2008

c DWR 2008

d For examples, see research by Richard Seager, Columbia University, available at http://www.ldeo.columbia.edu/res/div/ocp/drought/, or the California Global Climate Change Portal, available at http://www.climatechange.ca.gov

e California Ocean Protection Council 2011; other sources include higher projections

f DWR 2010

MAF: million acre-feet

The Delta Plan lays out 14 regulatory policies and 73 recommendations that start the process of addressing the current and predicted ecological, flood management, water quality, and water supply reliability challenges. As required by statute, the Delta Plan adopts a science-based adaptive management strategy to manage decision making in the face of uncertainty (Water Code section 85308(f)). All of these changes—some foreseeable, some not—will create a dynamic context in which the Delta Plan must adapt.

Over the life of the Delta Plan, the coequal goals of providing a more reliable water supply for California and restoring the Delta ecosystem are the foundation of all State water management policies. No water rights decisions or water contracts that directly or indirectly impact the Delta are made without consideration of the coequal goals. Over time, balanced application of the Public Trust Doctrine and the California Constitution, Article 10, Section 2 (requirements for beneficial use, reasonable water use, and no waste), have produced optimized water use, including high levels of water use efficiency and protection of public trust resources throughout the state. California has a comprehensive, fully integrated system for tracking and evaluating actual water use and water quality for both surface water and groundwater supplies.

The Delta Plan seeks first to arrest declining water reliability and environmental conditions related to the Delta ecosystem, and ultimately to improve them. It seeks to achieve a more resilient ecosystem that can absorb and adapt to current and future effects of multiple stressors. Additionally, it seeks to reduce flood risk, improve water quality, increase recreation opportunities in the Delta, and protect Delta legacy communities. Generally speaking, these are long-term goals to reduce and reverse increasing long-term environmental impacts caused by inaction. The vision of the Delta in 2100 will be realized through a series of near-term and longer-term actions informed by performance measures and overall adaptive management.

By 2100:

- **California's water supply** will be considerably more efficient, local and regional projects will be online to increase supplies and meet the demands of a growing population, and storage will have increased to meet the challenge of climate change and the needs of water transfer systems. Regions reliant on receiving some portion of their water from the Delta watershed will have reduced their reliance and improved regional self-reliance through increased conservation and diversification of their local and regional sources of supply. Delta conveyance will be managed in an adaptive manner that successfully balances ecosystem restoration and protection with more reliable water deliveries. Water quality in the Delta will support a healthy ecosystem and the multiple beneficial uses of water, including municipal supply and recreational uses such as fishing and swimming.
- **The Delta and Suisun Marsh ecosystem** will have the capacity to provide the environmental and societal benefits the public demands (viable populations of desired species, wild habitats for recreation and solace, land for agriculture, and the conveyance of reliable and high-quality fresh water). Large areas of the Delta will be restored in support of a healthy estuary. A diverse mosaic of interconnected habitats will be re-established in the Delta and its watershed. Migratory corridors for fish, birds, and terrestrial wildlife will be largely protected and restored. Actions have been taken to ensure that sufficient freshwater flows following a more natural, functional hydrograph are now dedicated to support a healthy ecosystem. Actions have reduced the impacts caused by stressors such as invasive species, poor water quality, loss of habitat, and urban development, resulting in improved conditions for native species of fish, birds, and wildlife that depend on the Delta and its watershed.

BDCP1738.

- **The Delta itself** will be a safe, nationally recognized and vibrant place, with well-defined cities and towns, a strong agricultural sector, and a well-deserved reputation as a recreational destination. Despite an increase in sea levels and altered runoff patterns, risks will be reduced, and residents and agencies will be prepared to respond when floods threaten. In 2100, the Delta will retain its rural heritage and be a place where agricultural, recreational, and environmental uses are uniquely integrated and continue to contribute in important ways to the regional economy.

Timeline for Implementing Priority Actions of the Delta Plan

Figure 1-5 contains a timeline for implementing the priority actions contained in the Delta Plan. The timeline emphasizes near-term and intermediate-term actions. In some instances, precedent or complementary actions need to be undertaken by other agencies or entities to ensure success of the Delta Plan.

Priority Action Timeline

TIMELINE

CHAPTER 1: Priority Actions

	ACTION (REFERENCE #)	LEAD AGENCY(IES)	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025	ACTION DEPENDS ON
POLICIES	**Reduce reliance on the Delta through improved regional water self-reliance** (WR P1)	Council, DWR, SWRCB	●	●	State, local water agency cooperation and compliance
	Delta flow objectives (ER P1)	SWRCB	●	●	SWRCB completes on time
	Prioritization of State investments in Delta levees and risk reduction (RR P1)	Council, DWR	●	●	Council completion; legislative adoption and implementation
RECOMMENDATIONS	**Update Delta flow objectives** (ER R1)	SWRCB	●	●	SWRCB completes on time
	Prioritize and implement projects that restore Delta habitat (ER R2)	DFW, DWR, Delta Conservancy	●	●	Funding, multiagency cooperation
	Designate the Delta as a National Heritage Area (DP R1)	DPC	●		Federal action, Congress
	Finance local flood management activities (RR R2)	DPC	●	●	
	Actions for the prioritization of State investments in Delta levees (RR R4)	Council, DWR	●		Council completion; legislative adoption and implementation
	Complete Bay Delta Conservation Plan (WR R12)	DWR, Council incorporates	●	●	State, federal agency action
	Complete surface water storage studies (WR R13)	DWR	●	●	
	Completion of regulatory processes, research, and monitoring for water quality improvements (WQ R8)	SWRCB, RWQCBs	●		
	Development of a Delta Science Plan (G R1)	Council	●	●	
OTHER	Complete Delta Finance Plan	Council	●		Ongoing funding
	Initiate Delta Plan Interagency Implementation Committee	Council	●	●	Agency cooperation
	Evaluate and update Delta Plan	Council	●		Ongoing funding

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Agency Key:

Council: Delta Stewardship Council
Delta Conservancy: Sacramento-San Joaquin Delta Conservancy
DFW: California Department of Fish and Wildlife
DPC: Delta Protection Commission
DWR: California Department of Water Resources
RWQCB: Regional Water Quality Control Board
SWRCB: State Water Resources Control Board

Figure 1-5

Organization of the Delta Plan

The Delta Plan is organized around the coequal goals and specific subgoals, strategies, actions, and measures set forth in the Delta Reform Act. The following chapters describe in detail the problems, expected outcomes, and performance measures associated with the various policies and recommendations:

- Chapter 2, The Delta Plan
- Chapter 3, A More Reliable Water Supply for California
- Chapter 4, Protect, Restore, and Enhance the Delta Ecosystem
- Chapter 5, Protect and Enhance the Unique Cultural, Recreational, Natural Resource, and Agricultural Values of the California Delta as an Evolving Place
- Chapter 6, Improve Water Quality to Protect Human Health and the Environment
- Chapter 7, Reduce Risk to People, Property, and State Interests in the Delta

In addition, Chapter 8, Funding Principles to Support the Coequal Goals, provides history and background for water project and program financing by discussing various funding schemes and by providing some current data on water-related expenditures in California. It also outlines guiding principles for developing stable financing for Delta Plan implementation and describes urgently needed near-term funding requirements for certain critical activities.

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Page 8: California Department of Water Resources

Page 14: Delta Conservancy

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CHAPTER 2

The Delta Plan

ABOUT THIS CHAPTER

This chapter discusses the purpose and role of the Delta Stewardship Council (Council) in the context of Sacramento-San Joaquin Delta (Delta) governance. It also describes the Council's approach to developing, implementing, and updating the Delta Plan, all within the framework of adaptive management. It describes why best available science and adaptive management are particularly important tools in the Delta, and proposes the development of a new Delta Science Plan to aid in the coordination and focus of science efforts across agencies. For State of California (State) or local agencies that propose a plan, program, or project occurring in whole or in part in the Delta, this chapter contains a description of the regulatory application of the Delta Plan. For instance:

- What is a covered action?
- Certifications of consistency
- Covered action consistency appeals

The chapter includes one policy and one recommendation.

RELEVANT LEGISLATION

The Sacramento-San Joaquin Delta Reform Act of 2009 established the Delta Stewardship Council to achieve more effective governance while providing for the sustainable management of the Delta ecosystem and a more reliable water supply, using an adaptive management framework, as reflected in the Water Code sections below.

> *85001 (c) By enacting this division, it is the intent of the Legislature to provide for the sustainable management of the Sacramento-San Joaquin Delta ecosystem, to provide for a more reliable water supply for the state, to protect and enhance the quality of water supply from the Delta, and to establish a governance structure that will direct efforts across state agencies to develop a legally enforceable Delta Plan.*
>
> *85020 (h) Establish a new governance structure with the authority, responsibility, accountability, scientific support, and adequate and secure funding to achieve these objectives.*
>
> *85022 (a) It is the intent of the Legislature that state and local land use actions identified as "covered actions" pursuant to Section 85057.5 be consistent with the Delta Plan. This section's findings, policies, and goals apply to Delta land use planning and development.*
>
> *85052 "Adaptive management" means a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives.*
>
> *85204 The council shall establish and oversee a committee of agencies responsible for implementing the Delta Plan. Each agency shall coordinate its actions pursuant to the Delta Plan with the council and the other relevant agencies.*
>
> *85211 The Delta Plan shall include performance measurements that will enable the council to track progress in meeting the objectives of the Delta Plan. The performance measurements shall include, but need not be limited to, quantitative or otherwise measurable assessments of the status and trends in all of the following:*
>
> > *(a) The health of the Delta's estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes, including viable populations of Delta fisheries and other aquatic organisms.*
> >
> > *(b) The reliability of California water supply imported from the Sacramento River or the San Joaquin River watershed.*
>
> *85225.5 To assist state and local public agencies in preparing the required certification, the council shall develop procedures for early consultation with the council on the proposed covered action.*
>
> *85225.10 (a) Any person who claims that a proposed covered action is inconsistent with the Delta Plan and, as a result of that inconsistency, the action will have a significant adverse impact on the achievement of one or both of the coequal goals or implementation of government-sponsored flood control programs to reduce risks to people and property in the Delta, may file an appeal with regard to a certification of consistency submitted to the council.*
>
> > *(b) The appeal shall clearly and specifically set forth the basis for the claim, including specific factual allegations, that the covered action is inconsistent with the Delta Plan. The council may request from the appellant additional information necessary to clarify, amplify, correct, or otherwise supplement the information submitted with the appeal, within a reasonable period.*
> >
> > *(c) The council, or by delegation the executive officer, may dismiss the appeal for failure of the appellant to provide information requested by the council within the period provided, if the information requested is in the possession or under the control of the appellant.*
>
> *85300(c) The council shall review the Delta Plan at least once every five years and may revise it as the council deems appropriate. The council may request any state agency with responsibilities in the Delta to make*

recommendations with respect to revision of the Delta Plan.

(d) (1) The council shall develop the Delta Plan consistent with all of the following:

(A) The federal Coastal Zone Management Act of 1972 (16 U.S.C. Sec.1451 et seq.), or an equivalent compliance mechanism.

(B) Section 8 of the federal Reclamation Act of 1902.

(C) The federal Clean Water Act (33 U.S.C. Sec. 1251 et seq.).

(2) If the council adopts a Delta Plan pursuant to the federal Coastal Zone Management Act of 1972 (16 U.S.C. Sec. 1451 et seq.), the council shall submit the Delta Plan for approval to the United States Secretary of Commerce pursuant to that act, or to any other federal official assigned responsibility for the Delta pursuant to a federal statute enacted after January 1, 2010.

85300(a) The Delta Plan shall include subgoals and strategies to assist in guiding state and local agency actions related to the Delta.

85302(e) The following subgoals and strategies for restoring a healthy ecosystem shall be included in the Delta Plan:

(1) Restore large areas of interconnected habitats within the Delta and its watershed by 2100.

(2) Establish migratory corridors for fish, birds, and other animals along selected Delta river channels.

(3) Promote self-sustaining, diverse populations of native and valued species by reducing the risk of take and harm from invasive species.

(4) Restore Delta flows and channels to support a healthy estuary and other ecosystems.

(5) Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals.

(6) Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds.

85300(a) The Delta Plan may also identify specific actions that state or local agencies may take to implement the subgoals and strategies.

85302(a) Implementation of the Delta Plan shall further the restoration of the Delta ecosystem and a reliable water supply.

85302(b) The Delta Plan may include recommended ecosystem projects outside the Delta that will contribute to achievement of the coequal goals.

85302(c) The Delta Plan shall include measures that promote all of the following characteristics of a healthy Delta ecosystem:

(1) Viable populations of native resident and migratory species.

(2) Functional corridors for migratory species.

(3) Diverse and biologically appropriate habitats and ecosystem processes.

(4) Reduced threats and stresses on the Delta ecosystem.

(5) Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations.

85302(d) The Delta Plan shall include measures to promote a more reliable water supply that address all of the following:

(1) Meeting the needs for reasonable and beneficial uses of water.

(2) Sustaining the economic vitality of the state.

(3) Improving water quality to protect human health and the environment.

85302(h) The Delta Plan shall include recommendations regarding state agency management of lands in the Delta.

85303 The Delta Plan shall promote statewide water conservation, water use efficiency, and sustainable use of water.

85304 The Delta Plan shall promote options for new and improved infrastructure relating to the water conveyance in the Delta, storage systems, and for the operation of both to achieve the coequal goals.

85305(a) The Delta Plan shall attempt to reduce risks to people, property, and state interests in the Delta by promoting effective emergency preparedness, appropriate land uses, and strategic levee investments.

85305(b) The council may incorporate into the Delta Plan the emergency preparedness and response strategies for the Delta developed by the California Emergency Management Agency pursuant to Section 12994.5.

85306 The council, in consultation with the Central Valley Flood Protection Board, shall recommend in the Delta Plan priorities for state investments in levee operation, maintenance, and improvements in the Delta, including both levees that are a part of the State Plan of Flood Control and nonproject levees.

85307(a) The Delta Plan may identify actions to be taken outside of the Delta, if those actions are determined to significantly reduce flood risks in the Delta.

85307(b) The Delta Plan may include local plans of flood protection.

85307(c) The council, in consultation with the Department of Transportation, may address in the Delta Plan the effects of climate change and sea level rise on the three state highways that cross the Delta.

85307(d) The council, in consultation with the State Energy Resources Conservation and Development Commission and the Public Utilities Commission, may incorporate into the Delta Plan additional actions to address the needs of Delta energy development, energy storage, and energy distribution.

85308 The Delta Plan shall meet all of the following requirements:

> *(a) Be based on the best available scientific information and the independent science advice provided by the Delta Independent Science Board.*
>
> *(b) Include quantified or otherwise measurable targets associated with achieving the objectives of the Delta Plan.*
>
> *(c) Where appropriate, utilize monitoring, data collection, and analysis of actions sufficient to determine progress toward meeting the quantified targets.*
>
> *(d) Describe the methods by which the council shall measure progress toward achieving the coequal goals.*
>
> *(e) Where appropriate, recommend integration of scientific and monitoring results into ongoing Delta water management.*
>
> *(f) Include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions.*

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CHAPTER 2

The Delta Plan

No single entity in California has the sole responsibility or authority for managing water supply and the Delta ecosystem. Instead, authority, expertise, and resources are spread out among a cadre of federal, State, and local agencies, with no single government agency empowered to provide leadership or a long-term vision. This is why governance reform enacted by the Delta Reform Act is fundamentally different from past approaches to managing the Delta. The milestone legislation created the Council, and gave it the direction and authority to serve two primary governance roles: (1) set a comprehensive, legally enforceable direction for how the State manages important water and environmental resources in the Delta through the adoption of a Delta Plan, and (2) ensure coherent and integrated implementation of that direction through coordination and oversight of State and local agencies proposing to fund, carry out, and approve Delta-related activities.

Recommended in significant part by the Delta Vision Task Force effort in 2008, this new approach is different from governance attempts over the past several decades that have tried, but largely failed, to provide effective and stable leadership. The *Delta Vision Strategic Plan* referred to some 200 agencies that play some role in managing the Delta's varied resources (Delta Vision 2008). One of the major goals articulated in that strategic plan was the establishment of a new governance structure with sufficient authority, responsibility, accountability, science support, and secure funding to achieve the coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The creation of the independent Council was a significant step toward implementing this goal. The Council is made up of seven members who provide a broad, statewide perspective and diverse expertise, and is advised by a 10-member board of nationally and internationally renowned scientists, the Delta Independent Science Board (ISB). The Delta Reform Act instructs the Council to "direct efforts across state agencies," but considerable challenges lie ahead in coordinating and supporting the multitude of agencies to achieve the goals of the Delta Plan.

The first major task for the newly created Council is the development of this Delta Plan. The Delta Reform Act requires the Council to develop and adopt a legally enforceable, long-term management plan for the Delta that uses best available science and is built upon the principles of adaptive management. The Delta Reform Act also established the Delta Science Program within the Council to provide the best possible unbiased scientific information to inform water and environmental decision making in the Delta. Because California's Delta is linked to so many statewide issues, described in Chapter 1, the Delta Plan's scope and purview encompasses statewide water use, flood management, and the Delta watershed, but with a specific focus on the legal Delta and Suisun Marsh. The Delta Plan contains a set of regulatory policies that will be enforced by the Council's appellate authority and oversight, described in this chapter. These regulatory policies and supporting documents are contained in Appendix B. The Delta Plan also contains priority recommendations, which are nonregulatory but call out actions essential to achieving the coequal goals. The Council has chosen to apply its regulatory authority in a targeted manner, and does so in an effort to ensure that all significant activities occurring in whole or in part in the Delta become better aligned over time with State policy priorities, including—and especially—the achievement of the coequal goals. The process for demonstrating compliance with Delta Plan policies is described in detail in this chapter.

In developing the first Delta Plan, the Council sought extensive public, stakeholder, and government agency input and, based on that input, developed the foundational set of policies and recommendations detailed in the following chapters to guide actions over the first few years of Plan implementation. Every stage of implementing the Delta Plan will necessitate leadership by the Council and ongoing coordination across a broad range of agencies, nongovernmental entities, and stakeholders.

The Delta Stewardship Council

As described in Chapter 1, the Delta of today is the result of centuries of natural and human-made actions and reactions. Government historically has worked to treat individual problems rather than adopt a systemwide approach. Dozens of agencies, task forces, and working groups have struggled to find the right combination of policy, science, and structure to address what are now California's fundamental goals for managing the Delta, the coequal goals.

The mission of the Council is to further the achievement of the coequal goals. To do so, the Council was charged with the development of a legally enforceable, long-term management plan for the Delta. To accomplish this, the Council will apply a common-sense approach based on a strong scientific foundation in an adaptive management framework to protect and restore the Delta ecosystem; improve the quality and reliability of California's water supplies; reduce risk to people, property, and State interests; and protect and enhance the Delta as an evolving place.

The Council's most important and challenging role is the facilitation, coordination, and integration of a range of actions and policies in support of the coequal goals. Implementation will occur through the Council's leadership of a formal Interagency Implementation Committee, ongoing informal staff-to-staff agency coordination, development of science to support the Delta Plan, and use of the Council's various authorities to ensure progress and accountability in how the Delta is managed. See Table 2-1 for a reference list of agencies with responsibilities in the Delta or related to the management of the Delta.

In addition to its role in setting State policy for the Delta in the Delta Plan, and in facilitating and coordinating agencies to achieve policy objectives, the Council was granted specific regulatory and appellate authority over certain actions that take place in whole or in part in the Delta. To do this, the Delta Plan contains a set of regulatory policies with which State and local agencies are required to comply. The Delta Reform Act specifically established a certification process for compliance with the Delta Plan. This means that State and local agencies that propose to carry out, approve, or fund a qualifying action in whole or in part in the Delta, called a "covered action," must certify that this covered action is consistent with the Delta Plan and must file a certificate of consistency with the Council that includes detailed findings. This process is described in the section "Covered Actions and Delta Plan Consistency" later in this chapter.

Agencies with Responsibilities in the Delta

TABLE 2-1

State	
Delta Stewardship Council	Established in 2009 by the Delta Reform Act to further the achievement of the coequal goals through the development and implementation of a legally enforceable Delta Plan.
California Department of Fish and Wildlife	Provides fish and wildlife protection and management, including management of wildlife areas and ecological reserves, public access, conservation planning, permitting, and implementation of the Ecosystem Restoration Program.
California Department of Water Resources	Owns and operates the State Water Project (which stores water upstream and conveys water through the Delta), has emergency response and flood planning responsibilities, holds water quality/supply contracts with Delta water agencies, and coordinates overall statewide water planning.
Delta Protection Commission	Prepares a comprehensive long-term resource management plan for land uses within the approximate 500,000-acre Primary Zone. Local government plans must be consistent.
Sacramento-San Joaquin Delta Conservancy	A primary State agency to implement ecosystem restoration in the Delta and also to assist/protect the region's agricultural, cultural, economic, and historical value.
State Water Resources Control Board	Required to develop in 2010 nonregulatory flow criteria for the Delta ecosystem necessary to protect public trust uses to inform planning proceedings for the Delta Plan and Bay Delta Conservation Plan (BDCP). Responsible for developing and implementing the Bay-Delta Water Quality Control Plan to establish water quality objectives, including flow objectives, to ensure reasonable protection of beneficial uses in the Bay-Delta. Responsible for establishing, implementing, and enforcing water right requirements to ensure the proper allocation and efficient use of water in and out of the Delta, including the role of the Delta Watermaster and implementation of the Bay-Delta Water Quality Control Plan. With regional boards, responsible for developing and implementing other water quality standards and control plans consistent with State and federal laws to reasonably protect aquatic beneficial uses.
California Emergency Management Agency	Plans, prepares emergency response, and coordinates the activities of all State agencies in connection to an emergency in the Delta; provides resources if local agencies are overwhelmed.
Central Valley Flood Protection Board	Plans flood control along the Sacramento and San Joaquin rivers and their tributaries in cooperation with the U.S. Army Corps of Engineers.
Office of the Delta Watermaster	Created in 2009 to oversee day-to-day administration of water rights, enforcement activities, and reports on water right activities regarding diversions in the Delta.
California Natural Resources Agency	Coordinates with a group of local water agencies, environmental and conservation organizations, State and federal agencies, and other interest groups developing the BDCP, a conservation strategy to be compliant with the Endangered Species Act (ESA) and Natural Community Conservation Planning Act, to be implemented over the next 50 years.
Other State agencies	Have various roles or responsibilities in the Delta relevant to the agency's concern (for example, California Department of Food and Agriculture, California Department of Transportation, California State Parks, California Department of Boating and Waterways, State Lands Commission, California Environmental Management Agency, and others).

Agencies with Responsibilities in the Delta

TABLE 2-1

Federal	
Bureau of Reclamation	Owns and operates the Central Valley Project, which, among other activities, pumps water through and out of the Delta.
U.S. Fish and Wildlife Service	Develops plans for the conservation and recovery of fish and wildlife resources, and addresses the variable needs of fish and wildlife pursuant to the ESA.
U.S. Army Corps of Engineers	Involved with both federal and nonfederal partners in assessing channel navigation, ecosystem, and flood risk management projects in the Delta. Works cooperatively with its nonfederal partners regarding the regulation, maintenance, and improvement of project levees in the Delta.
National Marine Fisheries Service	Develops plans for the conservation and recovery of salmonids in the Delta pursuant to the ESA.
U.S. Environmental Protection Agency	Responsible for protection and restoration of water quality in the Delta, pursuant to the Clean Water Act, which regulates the discharge of pollutants into waterways and sets standards for water quality. Oversees implementation of Clean Water Act programs and policies delegated to the State.
Other federal agencies	Various roles or responsibilities in the Delta relevant to the agency's concern (for example, U.S. Department of Agriculture, Natural Resources Conservation Service, and others).
Local	
Hundreds of local reclamation districts, resource conservation districts, water districts, city and county governments, and other special districts.	

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To be effective, governance to support science and implement adaptive management for a changing Delta must be flexible and have the capacity to change policies and practices in response to what is learned over time. An adaptive management approach as detailed in this chapter will ensure that the Delta Plan is updated as often as necessary to incorporate new information or modify policies and recommendations to ensure achievement of the coequal goals. The following section discusses the particular importance of science and adaptive management as they relate to the Delta.

Science and Adaptive Management in the Delta

The Delta Reform Act requires that the Delta Plan be based on and implemented using the best available science, and requires the use of science-based, transparent, and formal adaptive management strategies for ongoing ecosystem restoration and water management decisions. This section describes the importance of science, especially as it relates to the Delta, describes how the Delta Plan itself uses an adaptive management plan, and proposes the development of a Delta Science Plan as a companion to the Delta Plan.

The State of Bay-Delta Science report concluded that most of the decision making in the Delta was occurring on the basis of a false understanding that the Delta was a static system, and that "the Delta of the future would be much the same as the Delta of today" (Healey et al. 2008). Science indicates that significant changes are expected in the Delta over the coming decades, including climate change and the potential for earthquakes and flooding, as described in Chapter 1. In addition, current planning processes for habitat restoration, changes to water conveyance in the Delta, urban expansion, and other human drivers could reshape the Delta as we know it today.

The State of Bay-Delta Science urged a new perspective for decision making in the Delta (Healey et al. 2008). Decision making should be based on best available science, should account for risk and uncertainty, should acknowledge the dynamic nature of ecosystems, and should be responsive and adaptive to future change. The Delta Reform Act, enacted 1 year after that report, requires a strong science foundation for Council decisions. This includes the ongoing provision of scientific expertise to support the Council and other agencies through the Delta Science Program and Delta ISB. The Delta Science Program's mission is to provide the best possible scientific information for water and environmental decisions in the Bay-Delta system. The Delta ISB provides oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta to ensure that the application of the best science is used in Delta programs. The Delta ISB reviewed early drafts of this Delta Plan to ensure that the best science was used in the Delta Plan.

Why is it important that the Delta Plan emphasize science? First, science provides the basis of nearly all current understanding of the Delta's status (Healey et al. 2008, Lund et al. 2010). Second, new perspectives on science and policy in the Delta instill urgency for addressing the health of Delta ecosystems and the need for a more reliable water supply. Third, the interaction of multiple stressors to the ecosystem must be understood if they are to inform effective policy decisions.

Science and adaptive management are not simply academic exercises; they are tools that provide managers and decision makers an approach for using public funds more effectively, and increase the likelihood of success for a given project. Science by itself does not make or prioritize management decisions; it only informs actions and proposals. "Using the best science is only part of what is needed to resolve the competing interests…" that clamor over the Delta (NRC 2012).

The next sections describe what the Council means when it comes to best available science and adaptive management in the context of the coequal goals.

Best Available Science

Not all science is created equal nor deserves equal weight in decision making. Best available science provides the knowledge base for making sound decisions and is foundational for adaptive management. Best available science provides understanding for defining problems, developing conceptual models, identifying potential management actions, monitoring ecological and physical responses, and analyzing responses relative to the actions taken. Adaptive management both uses best available science and contributes to the creation of the best available science.

Best available science is specific to the decision being made and the time frame available for making that decision. There is no expectation of delaying decisions to wait for improved scientific understanding. Action may be taken on the basis of incomplete science if the information used is the best available at the time.

Best available science is developed through a process that meets the criteria of (1) relevance, (2) inclusiveness, (3) objectivity, (4) transparency and openness, (5) timeliness, and (6) peer review (NRC 2004). Best available science is consistent with the scientific process (Sullivan et al. 2006). Ultimately, best available science requires scientists using the best information and data to assist management and policy decisions. The processes and information used should be clearly documented and effectively communicated to foster improved understanding and decision making.

Under the Delta Plan, covered actions are required to demonstrate the use of best available science in their decision making (see policy G P1 in this chapter). Guidelines and criteria for identifying or developing best available science are provided in Appendix C.

SCIENCE IN THE DELTA – ADVANCES IN UNDERSTANDING

The following is a partial list of scientific advances that have changed understanding of the Delta and California's water supply over the last decade.

Effects of Climate Change on People and the Environment

- Increased frequency of (1) extreme water heights that cause floods, (2) water temperatures lethal to salmon and delta smelt, and (3) flooding in the Yolo Bypass, which will be much more common by the latter half of this century (Cloern et al. 2011).
- Trends in snowfall versus rainfall precipitation in the western United States show that temperatures have warmed during winter and early spring storms; and, consequently, the fraction of precipitation that falls as snow has declined while the fraction that falls as rain has increased. This shift from snowfall to rainfall will reduce natural water storage and is likely to increase risks of winter and spring flooding (Knowles et al. 2006).
- By mid-century, the Colorado River Reservoir System will not be able to meet all of the demands placed on it, including water supply for Southern California and the inland southwest, because reservoir levels will be reduced by over one-third and releases reduced by as much as 17 percent. Reductions in precipitation for the Colorado River Basin will threaten the ability to meet mandated water allocations (Barnett et al. 2004).

Water Supply Reliability

- The rate of groundwater depletion in the Central Valley was quantified using satellite imaging; approximately 2.5 million acre-feet per year of groundwater was lost during the period from October 2003 to March 2010 (Famiglietti et al. 2011).
- Precipitation and streamflow are proportionally more variable from year to year in California than in any other part of the United States (Dettinger et al. 2011).

Ecosystem Restoration

- Several open-water (pelagic) fish species have undergone steep declines known as the Pelagic Organism Decline (POD) (Sommer et al. 2007). The Interagency Ecological Program investigation of these declines led to new insights about the effects of multiple stressors on these species and the Delta ecosystem (summarized in Baxter et al. 2010). Improved knowledge about the POD also led to regulatory changes for water exports and pollutant discharges.
- In 86 percent of approximately 3,000 assessed streams across the United States, streamflow magnitudes (especially flow maxima and minima) were altered. In comparison to other evaluated stressors, streamflow alterations were found to have the greatest significance for explaining ecological impairment (Carlisle et al. 2011).
- Altered flow regimes by human activities influence the ecological impact of drought anomalies and increase the susceptibility of ecosystems to biological invasion. Extreme climatic events act together with environmental disturbances to enable the establishment of invasive species (Winder et al. 2011).
- Ratios of nutrients in Delta waters have been hypothesized to be a primary driver in the composition of aquatic food webs in the Bay-Delta (Glibert et al. 2011).

Water Quality

- Ammonium concentrations may be having a significant impact on phytoplankton composition and open-water food webs because of suppression of diatom blooms in the Bay-Delta (Dugdale et al. 2007).
- Pyrethroid pesticides largely derived from urban and suburban runoff are regularly found at levels that are toxic to aquatic invertebrates (Weston et al. 2005, Weston and Lydy 2010).

Risk Reduction

- With permanently flooded conditions and managed water depths, short-term sediment accretion rates as high as 7 to 9 centimeters per year can be obtained to help reverse subsidence on Delta islands (Miller et al. 2008).
- Atmospheric rivers (narrow corridors of concentrated moisture in the atmosphere) contribute 33 to 50 percent of the total average amount of rainfall for California and have been the source of many floods along the West Coast of the United States. California's water resources and floods come from the same storms to an extent, which makes integrated flood and water resources management all the more important (Dettinger et al. 2011).

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Adaptive Management

Adaptive management is defined in the Delta Reform Act as:

> *a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives (Water Code section 85052).*

Adaptive management is useful in that it provides flexibility and feedback to manage natural resources in the face of often considerable uncertainty. This approach requires careful science-based planning followed by measurement to determine whether a given action actually achieves intended goals.

If goals are not achieved, informed adjustments can be made. This is especially important in the context of the Delta because, in some instances, competing and uncertain explanations arise, and decision making cannot be delayed until causes are better understood (Healey et al. 2008). The Council has adopted a three-phase adaptive management framework for the purposes of developing, implementing, and updating the Delta Plan, described later in this chapter, and also for use by ecosystem restoration and water management covered actions, as set forth in G P1 with additional detail in Appendix C.

A Delta Science Plan

Multiple frameworks for science in the Delta have been proposed, but a comprehensive science plan that specifies how scientific research, monitoring, analysis, and data management will be coordinated among entities has yet to be developed. Currently, science efforts in the Delta are performed by multiple entities with varying missions and mandates, and without an overarching plan. The National Research Council (NRC) found that "only a synthetic, integrated, analytical approach to understanding the effects of suites of environmental factors (stressors) on the ecosystem and its components is likely to provide important insights that can lead to enhancement of the Delta and its species" (NRC 2012). Therefore, a comprehensive science plan for the Delta is needed to organize and integrate ongoing scientific research, monitoring, and learning about the Delta as it changes over time.

A Delta Science Plan will guide efficient use of resources for balancing investments in addressing short-term science needs and those that build understanding over the long run. This plan will address effective governance for science in the Delta, strategies for addressing uncertainty and conflicting scientific information, the prioritization of research, near-term science needs, financial needs to support science, and more. Such a plan is essential to support the adaptive management of ecosystem restoration and water management decisions in the Delta.

Additional detail regarding the proposed Delta Science Plan is provided in recommendation G R1 in this chapter.

The Delta Plan

The Delta Reform Act established the Council and directed it to develop an overarching, long-term management plan for the Delta. Figure 2-1 shows the roles assigned to the Council under the Act. The Act specifically requires that this plan for the Delta include a science-based, formal adaptive management strategy for ongoing ecosystem restoration and water management decisions.

This section presents a three-phase adaptive management framework (Plan, Do, and Evaluate and Respond), describes specific considerations that went into the development of the Delta Plan, and provides the overarching framework for how the Council (in collaboration with others) will implement and continuously amend the Delta Plan to achieve the coequal goals.

Council Roles and the Delta Plan

Council Roles and the Delta Plan

COORDINATE
- Develop, implement, and update Delta Plan
- Establish and oversee Interagency Implementation Committee

ENSURE CONSISTENCY
- Determine consistency of covered actions upon appeal
- Advise local and regional agencies on consistency with Delta Plan

INFORM

Adaptive management of the Delta Plan: Develop and use best available science and information to inform decision making in the Delta

COMMENT

Review and comment on environmental impact reports and other Delta-related programs and projects

ENSURE ACCOUNTABILITY
- Hold hearings
- Request reports
- Track performance measures

BDCP OVERSIGHT
- Serve as responsible agency on EIR
- Independent appellate role

Figure 2-1

The Council’s Three-phase Adaptive Management Framework

Several existing frameworks for adaptive management provide the basis for the Delta Plan’s own adaptive management approach.[1] Although there are differences among various frameworks, they generally consist of three broad phases: Plan, Do, and Evaluate and Respond. Throughout all three phases of the adaptive management process, decisions are made by managers, policy makers, and/or technical experts. In developing an adaptive management plan, the best available science should be used to inform all phases of the adaptive management process.

In addition to requiring adaptive management for certain proposed covered actions, the Council, in coordination with others, will use adaptive management to develop, implement, and update the Delta Plan. The Council will rely in large part on the Delta Science Program to determine the relevance, value, and reliability of the best available science and to organize that information for its use in the Council’s decisions. The Council has the final responsibility for determining the best available science used in support of its actions, including when a choice among competing interpretations of available science must be made.

The three phases of the Council’s adaptive management framework (Plan, Do, and Evaluate and Respond) are shown on Figure 2-2, and are further broken down into nine steps, which are described in detail in Appendix C.

The Delta Stewardship Council’s Three-phase Adaptive Management Framework

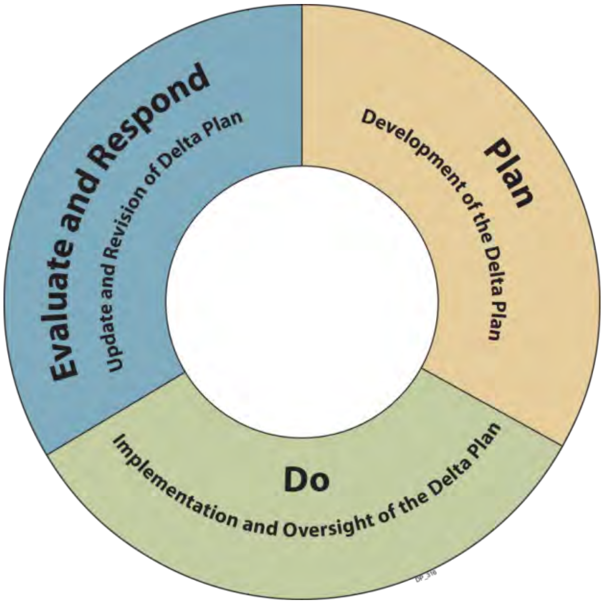

Figure 2-2

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[1] Christensen et al. 1996, Stanford and Poole 1996, CALFED Bay-Delta Program 2000, Habron 2003, Abal et al. 2005, Healey et al. 2008, Kaplan and Norton 2008, Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management 2009, Williams et al. 2009.

Plan: Development of the Delta Plan

The first phase of adaptive management is "Plan." The Plan phase requires clear definition of the problem, establishment of objectives, how to achieve those objectives, and actions for implementation. Performance measures are included to evaluate whether the actions are successfully meeting their intended objectives. As described in Chapter 1, the Council was established in response to an ongoing crisis in the Delta. Water supply reliability and the health of the Delta ecosystem are both at risk, and the status quo—including the patchwork governance of State, local, and federal agencies—is not making acceptable progress toward reversing disturbing trends in a balanced and sustainable manner.

The Delta Plan is intended to be foundational and adaptive. It is foundational in that the Council has built on previous efforts, including CALFED, the Delta Vision, the California Water Plan, planning efforts of the State Water Resources Control Board (SWRCB), the Delta Protection Commission (DPC), and others. The framework established in this Delta Plan is intended to advance the coequal goals of water supply reliability and ecosystem health, and to employ adaptive management to improve the Plan over time.

This Delta Plan officially supersedes and replaces the Interim Delta Plan adopted by the Council on August 27, 2010.

Structure of the Delta Plan

The Delta Plan contains five core policy chapters (Chapters 3 through 7) and a chapter on Funding Principles to Support the Coequal Goals (Chapter 8). The narrative sections of each policy chapter provide subject matter context and rationale for the selection and implementation of core strategies. These core strategies are then broken down into actions: the policies and recommendations. The policies in the Delta Plan are regulatory in nature, and compliance is required for those who propose covered actions. In each policy chapter, the Policies and Recommendations section is followed by a section identifying both science needs and key issues for future evaluation by the Council.

Finally, each policy chapter concludes with a set of performance measures. The Delta Reform Act requires that the Delta Plan include performance measures to evaluate whether it is achieving its objectives over time. Information learned from performance measures will be an important part of how the Council determines when and how to update the Delta Plan as part of the Evaluate and Respond phase of the adaptive management process. See the sidebar, Performance Measures in the Delta Plan, later in this chapter.

Considerations in the Development of the Delta Plan

The Delta Reform Act set forth certain requirements and guidance for the development of the Delta Plan. The Act required the development of several State agency plans to inform the Delta Plan planning process and set forth statutory guidelines for the consideration or inclusion of certain plans, some of which were not yet completed at the date of Delta Plan publication and will be considered in future plan updates.

- **Delta Reform Act objectives.** The Act lists numerous objectives and, in some sections, provides detailed guidance for what the Delta Plan shall include (see Table 2-2).
- **State agency proposals.** Specific agencies are named in the Delta Reform Act as being responsible for submitting reports or recommendations to the Council for consideration for inclusion in the Delta Plan. The DPC, California State Parks, and the California Department of Food and Agriculture (CDFA) all submitted proposals that were considered in the development of this Delta Plan.
- **Consistency with federal law.** The Delta Reform Act requires that the Delta Plan be developed consistent with the federal Clean Water Act, Section 8 of the federal Reclamation Act of 1902, and the federal Coastal Zone Management Act of 1972 (CZMA), or an equivalent compliance mechanism. See sidebar, Federal Participation in Implementing the Delta Plan, for more information.

Delta Plan Requirements by Water Code Section

TABLE 2-2

Water Code Section	Requirement
85211	The Delta Plan shall include performance measurements that will enable the council to track progress in meeting the objectives of the Delta Plan. The performance measurements shall include, but need not be limited to, quantitative or otherwise measurable assessments of the status and trends in all of the following:
85211(a)	– The health of the Delta's estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes, including viable populations of Delta fisheries and other aquatic organisms.
85211(b)	– The reliability of California water supply imported from the Sacramento River or the San Joaquin River watershed.
85300(a)	The Delta Plan shall include subgoals and strategies to assist in guiding state and local agency actions related to the Delta.
85302(e)	The following subgoals and strategies for restoring a healthy ecosystem shall be included in the Delta Plan:
85302(e)(1)	– Restore large areas of interconnected habitats within the Delta and its watershed by 2100.
85302(e)(2)	– Establish migratory corridors for fish, birds, and other animals along selected Delta river channels.
85302(e)(3)	– Promote self-sustaining, diverse populations of native and valued species by reducing the risk of take and harm from invasive species.
85302(e)(4)	– Restore Delta flows and channels to support a healthy estuary and other ecosystems.
85302(e)(5)	– Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals.
85302(e)(6)	– Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds.
85300(a)	The Delta Plan may also identify specific actions that state or local agencies may take to implement the subgoals and strategies.
85302(a)	Implementation of the Delta Plan shall further the restoration of the Delta ecosystem and a reliable water supply.
85302(b)	The Delta Plan may include recommended ecosystem projects outside the Delta that will contribute to achievement of the coequal goals.
85302(c)	The Delta Plan shall include measures that promote all of the following characteristics of a healthy Delta ecosystem:
85302(c)(1)	– Viable populations of native resident and migratory species.
85302(c)(2)	– Functional corridors for migratory species.
85302(c)(3)	– Diverse and biologically appropriate habitats and ecosystem processes.
85302(c)(4)	– Reduced threats and stresses on the Delta ecosystem.
85302(c)(5)	– Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations.
85302(d)	The Delta Plan shall include measures to promote a more reliable water supply that address all of the following:
85302(d)(1)	– Meeting the needs for reasonable and beneficial uses of water.
85302(d)(2)	– Sustaining the economic vitality of the state.
85302(d)(3)	– Improving water quality to protect human health and the environment.
85302(h)	The Delta Plan shall include recommendations regarding state agency management of lands in the Delta.

Delta Plan Requirements by Water Code Section

TABLE 2-2

Water Code Section	Requirement
85303	The Delta Plan shall promote statewide water conservation, water use efficiency, and sustainable use of water.
85304	The Delta Plan shall promote options for new and improved infrastructure relating to the water conveyance in the Delta, storage systems, and for the operation of both to achieve the coequal goals.
85305(a)	The Delta Plan shall attempt to reduce risks to people, property, and state interests in the Delta by promoting effective emergency preparedness, appropriate land uses, and strategic levee investments.
85305(b)	The council may incorporate into the Delta Plan the emergency preparedness and response strategies for the Delta developed by the California Emergency Management Agency pursuant to Section 12994.5.
85306	The council, in consultation with the Central Valley Flood Protection Board, shall recommend in the Delta Plan priorities for state investments in levee operation, maintenance, and improvements in the Delta, including both levees that are a part of the State Plan of Flood Control and nonproject levees.
85307(a)	The Delta Plan may identify actions to be taken outside of the Delta, if those actions are determined to significantly reduce flood risks in the Delta.
85307(b)	The Delta Plan may include local plans of flood protection.
85307(c)	The council, in consultation with the Department of Transportation, may address in the Delta Plan the effects of climate change and sea level rise on the three state highways that cross the Delta.
85307(d)	The council, in consultation with the State Energy Resources Conservation and Development Commission and the Public Utilities Commission, may incorporate into the Delta Plan additional actions to address the needs of Delta energy development, energy storage, and energy distribution.
85308	The Delta Plan shall meet all of the following requirements:
85308(a)	– Be based on the best available scientific information and the independent science advice provided by the Delta Independent Science Board.
85308(b)	– Include quantified or otherwise measurable targets associated with achieving the objectives of the Delta Plan.
85308(c)	– Where appropriate, utilize monitoring, data collection, and analysis of actions sufficient to determine progress toward meeting the quantified targets.
85308(d)	– Describe the methods by which the council shall measure progress toward achieving the coequal goals.
85308(e)	– Where appropriate, recommend integration of scientific and monitoring results into ongoing Delta water management.
85308(f)	– Include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions.

- **Incorporation of the Bay Delta Conservation Plan into the Delta Plan.** The Bay Delta Conservation Plan (BDCP) is a major project considering large-scale improvements in water conveyance and large-scale ecosystem restoration in the Delta. When completed, it must be incorporated into the Delta Plan if it meets certain statutory requirements. Completion of the BDCP process and the number of projects now under consideration in that process would have large impacts on the Delta and would affect the coequal goals. (More detailed discussions of the BDCP are provided in Chapters 3 and 4.) The Delta Reform Act describes a separate, explicit process for incorporating the BDCP into the Delta Plan (Water Code section 85320), and the

Council has adopted administrative procedures governing appeals to the Council related to BDCP incorporation (see Appendix D). If the BDCP is incorporated into the Delta Plan, it becomes part of the Delta Plan and, therefore, part of the basis for future consistency determinations.

- **Incorporation of other plans into the Delta Plan.** The Council may incorporate other plans or programs in whole or in part into the Delta Plan to the extent that they promote the coequal goals.

Do: Implementation and Oversight of the Delta Plan

The second phase of adaptive management is "Do." The "doing," or implementation, of the Delta Plan will occur over time (through 2100) through the coordinated efforts of many State, local, and federal agencies, in cooperation with nongovernmental organizations and private parties, and Council oversight and exercise of appellate authorities.

Federal participation in implementing the Delta Plan and the coequal goals is described in detail in the sidebar, Federal Participation in Implementing the Delta Plan.

The Council is responsible for overseeing the Delta Plan's implementation. Given the numerous government agencies that frequently have conflicting or overlapping jurisdictional and programmatic interest in Delta matters (see Table 2-1), there is a compelling need for the Council to fulfill the role as integrator of Delta policy and coordinator of actions. This integration and coordination will occur through convening a formal Interagency Implementation Committee, providing ongoing informal staff-to-staff agency coordination, providing comments and advice from the Council to other agencies on proposed or ongoing plans and programs, holding public hearings, developing science to support the Delta Plan, and using the Council's appellate authority over consistency of significant actions in the Delta with the Delta Plan.

Delta Plan Interagency Implementation Committee

Perhaps the most significant tool the Council will have for implementing the Delta Plan and ensuring accountability is a formal method for active agency coordination. The Delta Reform Act directs the Council to establish and oversee a committee of agencies responsible for implementing the Delta Plan. Notably, the law states that "each agency shall coordinate its actions pursuant to the Delta Plan with the Council and other relevant agencies" (Water Code section 85204). Governance challenges have long plagued management of the Delta and California's ability to achieve stated objectives for water supply and the Delta ecosystem. Ambiguous and sometimes conflicting authorities and responsibilities among agencies thwart real progress (NRC 2012).

The Council, therefore, will coordinate implementation of the Delta Plan through the establishment and leadership of an Interagency Implementation Committee to do the following:

- Monitor progress of priority actions and agency activities to implement the Delta Plan;
- Report regularly on implementation plans and actions;
- Identify opportunities for integration and leveraging of funding;
- Identify funding needs and support development of a finance plan to implement the Delta Plan;
- Assist in the ongoing development and tracking of Delta Plan performance measures;
- Coordinate regulatory actions on significant projects to implement the Delta Plan, as appropriate; and
- Discuss common issues and resolve interagency conflicts.

The Interagency Implementation Committee, which shall convene at least twice each year and more often as needed, will be overseen by the Council and will be organized around the implementation of the Delta Plan. The Interagency Implementation Committee will include federal, local, and State agency representatives as dictated by the specific matter or subject area in the Delta Plan. At a minimum, the Interagency Implementation Committee will consist of the Council's Executive Officer, the Delta Science Program lead

FEDERAL PARTICIPATION IN IMPLEMENTING THE DELTA PLAN

The Delta Reform Act recognizes the federal government's critical role in achieving the coequal goals through the Delta Plan's comprehensive, Delta-wide planning and implementation effort. This effort goes beyond federal participation in the more narrowly focused BDCP. This recognition builds upon the history of federal-State cooperative governance efforts in the Delta made necessary by the multitude of federal and State agencies working on interconnected, cross-jurisdictional issues in and related to the Delta, including water project operations, water quality regulation, levee maintenance, habitat restoration, and endangered species regulation.

Federal Law Now Incorporates the Coequal Goals

The federal Energy and Water Development Appropriations Act of 2012 (Title II of the Consolidated Appropriations Act of 2012 (PL 112-074)) contains, in pertinent part, the following:

> *The Federal policy for addressing California's water supply and environmental issues related to the Bay-Delta shall be consistent with State law, including the coequal goals of providing a more reliable water supply for the State of California and protecting, restoring, and enhancing the Delta ecosystem…Nothing herein modifies existing requirements of Federal law. (Section 205)*

The Council's staff will work with federal agency representatives to explore opportunities for federal participation in Delta Plan implementation efforts to help those agencies comply with this new Congressional policy directive.

The current regulatory provisions of the Delta Plan, including the consistency review and appeals process, apply to only covered actions of State and local agencies. However, once the Delta Plan is adopted, the Delta Reform Act requires the Council to pursue a compliance mechanism that requires consistency of federal actions. The Delta Reform Act identifies the CZMA, or "an equivalent compliance mechanism," as the preferred means to accomplish this objective. Under the CZMA, states are authorized to review certain activities of federal agencies, including activities directly conducted by federal agencies and activities permitted or licensed by these agencies, for consistency with a state's federally approved coastal management program. This review authority applies to any activity that affects any land or water use or natural resource of the state coastal zone.

In this regard, the Council staff has met, and will continue to meet, with federal agency representatives to identify the appropriate process to submit the Delta Plan to the Secretary of Commerce for approval under the CZMA (and with representatives of the California Coastal Commission and the San Francisco Bay Conservation and Development Commission, which administer California's coastal management program).

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scientist, and executive officers or directors from the California Department of Water Resources (DWR); California Department of Fish and Wildlife (DFW); SWRCB and regional water quality control boards; the San Francisco Bay Conservation and Development Commission; the California Water Commission; the Sacramento-San Joaquin Delta Conservancy; the DPC; the Delta Watermaster; the CDFA; the Natural Resources Agency; the Business, Transportation and Housing Agency; and the California Environmental Protection Agency. Federal agencies such as National Oceanic and Atmospheric Administration Fisheries, U.S. Fish and Wildlife Service, Bureau of Reclamation, Natural Resources Conservation Service, U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and others, as appropriate, will be invited to participate and provide status reports on various projects and programs related to Delta Plan implementation.

The meetings of the Interagency Implementation Committee will be open to the public, and the agenda will be noticed in advance. The committee will create ad hoc workgroups as appropriate to facilitate focus on specific issues. Stakeholder representatives will be encouraged to participate in the various workgroups. The work of both the formal Interagency Implementation Committee and the workgroups may be supplemented with meetings or hearings conducted by the Council.

The Delta Protection Commission's Role in Delta Plan Implementation

The Delta Protection Act states that the DPC is the appropriate agency to identify and provide recommendations to the Council on methods of preserving the Delta as an evolving place. The DPC developed and submitted a set of recommendations to the Council, many of which were incorporated in this Delta Plan (DPC 2012). The Delta Protection Act outlines a process for the DPC to review and provide comments and recommendations to the Council on any significant project or proposed project within the scope of the Delta Plan that may affect the unique values of the Delta (Public Resources Code section 29773(a)). The Council's adopted procedures include a process whereby the Council will notify the DPC of covered action appeals.

Other Delta Plan Implementation Actions

In addition to convening the Interagency Implementation Committee and carrying out the other responsibilities assigned to it by the Delta Reform Act, the Delta Plan assigns other tasks that will further refine the Delta Plan to the Council. These tasks are described in the following recommendations: G R1 (Chapter 2), WR R5 (Chapter 3), WR R15 (Chapter 3), DP R7 (Chapter 5), DP R19 (Chapter 5), RR R4 (Chapter 7), and FP R1 through R3 (Chapter 8).

Additional Council Authorities in Implementing the Delta Plan

The Delta Reform Act enumerated a range of specific authorities for the Council related to the implementation of the Delta Plan (as shown on Figure 2-1). A full list of authorities can be found in Water Code section 85210 and in various sections of the Delta Reform Act. In implementing the Delta Plan, the Council has the authority to:

- **Comment on environmental impact reports.** The Council has a role in commenting on any State agency environmental impact reports (EIRs) as appropriate to the mission of the Council.
- **Comment on policies related to the coequal goals and implementation of the Delta Plan.** As appropriate, the Council may comment formally on any proposed policies or regulations that will impact the achievement of the coequal goals and the implementation of the Delta Plan.
- **Advise local governments.** The Council has a role in advising local and regional planning agencies regarding the consistency of their planning documents with the Delta Plan. As described in Chapter 5, the Council will review sustainable community strategies and regional transportation plans to prevent conflicts with the Delta Plan and to coordinate metropolitan development with actions in the Delta.
- **Request reports from State, federal, and local agencies.** The Council has the authority to request reports from agencies on issues related to the implementation of the Delta Plan.
- **Hold hearings.** The Council has the authority to hold hearings in all parts of the state and to subpoena witnesses.
- **Develop, coordinate, and promote the use of science through the Delta Science Program.** The Council has a role in providing the best available unbiased scientific information to inform water and environmental decision making in the Delta by funding research, synthesizing and communicating scientific information to policy makers and decision makers, promoting independent peer review, and coordinating with Delta agencies to promote science-based adaptive management.
- **Make consistency determinations upon appeal.** The Legislature intended that State and local actions that would have a significant impact on the coequal goals or a government-sponsored flood control program be consistent with the Delta Plan. The Council has the authority to implement the Delta Plan in part through the enforcement of consistency of covered actions with the Delta Plan upon appeal. The Delta Reform Act also gave the Council a specific appellate role with respect to the BDCP and its future incorporation into the Delta Plan. The Council's appellate roles, the definition of a covered action, and the consistency determination process and appeals process are described in detail in the Covered Actions and Delta Plan Consistency section later in this chapter.

Monitoring Progress toward Achieving the Coequal Goals

The Council will use existing monitoring efforts (such as the efforts of the Interagency Ecological Program, California Water Quality Monitoring Council, and California Statewide Groundwater Elevation Monitoring) and new monitoring efforts to inform progress toward achieving the performance measures in the Delta Plan. The Council will monitor the progress of programs and projects toward achieving the administrative, output, and outcome performance measures in the current Delta Plan and those developed in the future. Working with others, in particular the Interagency Implementation Committee, the Council will use coordinated information about relevant status and trends and progress toward meeting the coequal goals to inform revisions to the Delta Plan. The Council's monitoring activities will be reported on the Council website.

Evaluate and Respond: Updating and Amending the Delta Plan

The third phase of Delta Plan adaptive management is "Evaluate and Respond." According to the Delta Reform Act, the Council must review the Delta Plan at least once every 5 years and can revise it as the Council deems appropriate. This authority is consistent with the Council's obligation to base the Delta Plan on the best available scientific information and to use an adaptive management approach in updating the Plan as new information becomes available.

When updating the Delta Plan, the Council will consider information from other adaptive management activities in the Delta; evaluation of Delta Plan policies and recommendations; performance measures; other completed plans related to the Delta; and coordination, hearings, and oversight. The Council will rely in large part on the Delta Science Program for determining the relevance, value, and reliability of the best available science, and organizing that information for its use in the Council's decisions. The Council has the final responsibility for determining the best available science used in support of its actions, including when a choice among competing interpretations of available science must be made.

Reporting on Delta Plan Performance Measures

This Delta Plan contains preliminary performance measures developed to monitor performance of Delta Plan policies and recommendations. (See sidebar, Performance Measures in the Delta Plan, for more detailed information.) Upon adoption of the Delta Plan, staff will take the lead, working with scientific, agency, and stakeholder experts to continue to refine the Delta Plan's performance measures. Delta Plan performance measures will be periodically reviewed by independent expert review panels and will be sent to the Delta ISB for further review and comment. The resulting updated performance measures will be developed no later than December 31, 2014, for consideration by the Council for incorporation into the Delta Plan. The Council will issue periodic public reports on the status of performance measures.

Data collection related to the Delta and water management in California is already occurring, although more is needed. The Council, through the Interagency Implementation Committee and working with stakeholders, will report regularly on Delta Plan performance measures and the Delta Plan's progress in advancing the coequal goals. These reports will be made available to the public.

PERFORMANCE MEASURES IN THE DELTA PLAN

The performance measures included in this Delta Plan are primarily administrative measures focused on implementation of near-term actions (generally, actions contained within policies and recommendations of the Delta Plan) that support the coequal goals. This initial set of performance measures will be expanded and refined after adoption of the Delta Plan and will be considered for inclusion in subsequent updates of the Delta Plan.

Delta Plan performance measures have been placed into three general classes:

- Administrative performance measures describe decisions made by policy makers and managers to finalize plans or approve resources (funds, personnel, projects) for implementation of a program or group of related programs.
- Output (also known as "driver") performance measures evaluate the factors that may be influencing outcomes and include on-the-ground implementation of management actions, such as acres of habitat restored or acre-feet of water released, as well as natural phenomena outside of management control (such as a flood, earthquake, or ocean conditions).
- Outcome performance measures evaluate responses to management actions or natural outputs.

Administrative performance measures are included in Appendix E. Output and outcome performance measures, where appropriate, are included at the end of individual chapters.

Development of informative and meaningful performance measures is a challenging task that will continue after the adoption of the Delta Plan. Performance measures need to be designed to capture important trends and to address whether specific actions are producing expected results. Efforts to develop performance measures in complex and large-scale systems like the Delta are commonly multiyear endeavors. The Council will improve all performance measures, but will focus on outcome measures through a multiyear effort, using successful approaches for developing performance measures employed by similar efforts elsewhere (such as the Kissimmee River Restoration, The State of San Francisco Bay, and Healthy Waterways Southeast Queensland, Australia) as positive examples (see Appendix C for more information).

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Communication and the Delta Plan

Keeping the public and decision makers informed as future Delta Plan changes are proposed and considered is a vital step. The Council is committed to open communication of current understanding gained through the evaluation of performance measures, monitoring, science, and adaptive management. This communication will be continuous as the Council receives and produces information that will be used to adapt its strategy toward meeting the coequal goals and updating the Delta Plan.

The Council's website and meetings will remain the central hub for communicating information about progress toward meeting the coequal goals and the objectives of the Delta Plan. Information learned from the analysis, synthesis, and evaluation of how well the policies and recommendations in the Delta Plan are meeting their intended goals will be gathered and communicated through a number of media and forums that may include:

- The Council's meetings and workshops, website, social media, and newsletter
- Staff reports on the status and trends of the Delta Plan performance measures
- Reports, presentations, and correspondence presented to the Council
- Interagency Implementation Committee meetings and products
- The Delta Science Program website, *Science News*; the online journal, *San Francisco Estuary & Watershed Science*; brown bag seminars; and Biennial Bay-Delta Science Conference
- Delta ISB meetings and products

Covered Actions and Delta Plan Consistency

The Delta Reform Act directs the Council to develop a legally enforceable long-term management plan for the Delta (this Delta Plan) and includes a mechanism for enforcement of Delta Plan policies over State and local actions identified as covered actions (Water Code sections 85001(c) and 85022). The Council has taken a hybrid approach to developing the Delta Plan by including both regulatory policies and nonregulatory recommendations. This section presents a discussion of the process and general requirements for certifying consistency with the Delta Plan through compliance with its regulatory policies, and includes examples of covered actions and exemptions.

Delta Plan regulatory policies are not intended and shall not be construed as authorizing the Council or any entity acting pursuant to this section to exercise their power in a manner that will take or damage private property for public use without the payment of just compensation. These policies are not intended to affect the rights of any owner of property under the Constitution of the State of California or the United States. None of the Delta Plan policies increases the State's flood liability.

Covered Actions Must Comply with Delta Plan Policies

The Delta Reform Act requires State and local actions that fit the legal definition of a covered action to be consistent with the policies included in the Delta Plan. The mechanism for determining consistency is the filing of a certification of consistency. Not all actions that occur in whole or in part in the Delta are covered actions. Only certain activities qualify as covered actions, and the Delta Reform Act establishes specific criteria and exclusions, discussed in this chapter. Furthermore:

- The State or local agency that carries out, approves, or funds a proposed action determines whether that proposed plan, program, or project is a covered action (subject to judicial review of whether the determination was reasonable and consistent with the law).
- The State or local agency that carries out, approves, or funds a covered action ("proponents") needs to certify consistency with the policies included in the Delta Plan.
- In the case of all other actions (those that do not meet the criteria of being a covered action or are otherwise explicitly excluded), the Delta Plan's policies, where applicable, are recommendations.

What Is a Covered Action?

For a State or local agency to determine whether its proposed plans, programs, or projects are covered actions under the Delta Plan and, therefore, subject to the regulatory provisions in the plan, it must start with the Delta Reform Act, which defines a covered action as (Water Code section 85057.5(a)):

> *…a plan, program, or project as defined pursuant to Section 21065 of the Public Resources Code that meets all of the following conditions:*
>
> 1. *Will occur, in whole or in part, within the boundaries of the Delta or Suisun Marsh;*
> 2. *Will be carried out, approved, or funded by the state or a local public agency;*
> 3. *Is covered by one or more provisions of the Delta Plan;*
> 4. *Will have a significant impact on the achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta.*

Figure 2-3 shows the steps to follow for identifying whether a proposed plan, project, or program is a covered action.

Screening Criteria for Covered Actions

As used in this Delta Plan, the statutory criteria for covered actions under the Delta Plan are collectively referred to as "screening criteria." Before using the screening criteria, a project proponent should first determine whether its proposed plan, program, or project is exempt from covered action status under either the Council's administrative exemptions or the Delta Reform Act's statutory exemptions, discussed below. Early consultation with Council staff is encouraged and can assist in this determination.

1. **Is a "Project," as defined by section 21065 of the Public Resources Code.** A proponent's first step in determining whether a plan, program, or project is a covered action is to identify whether it meets the definition of a project as defined in Public Resources Code section 21065. That particular provision is the section of the California Environmental Quality Act (CEQA) that defines the term "project" for purposes of potential review under CEQA.[2] If the plan, program, or project does indeed meet the definition of a project under CEQA, the next step in determining a covered action is to review the four additional screening criteria in the definition of covered action, *all* of which must be met by a proposed plan, program, or project for it to qualify as a covered action (see sidebar, What Does CEQA Consider a "Project"?).

2. **Will occur in whole, or in part, within the boundaries of the Delta or Suisun Marsh.** To qualify as a covered action, a project must include one or more activities that take place at least partly within the Delta or Suisun Marsh. This means, for example, that the diversion and use of water in the Delta watershed that is entirely upstream of the statutory Delta or Suisun Marsh would not satisfy this criterion. By contrast, this criterion *would* be met if water intended for use upstream were transferred through the statutory Delta or Suisun Marsh (pursuant, for example, to a water transfer longer than 1 year in duration).

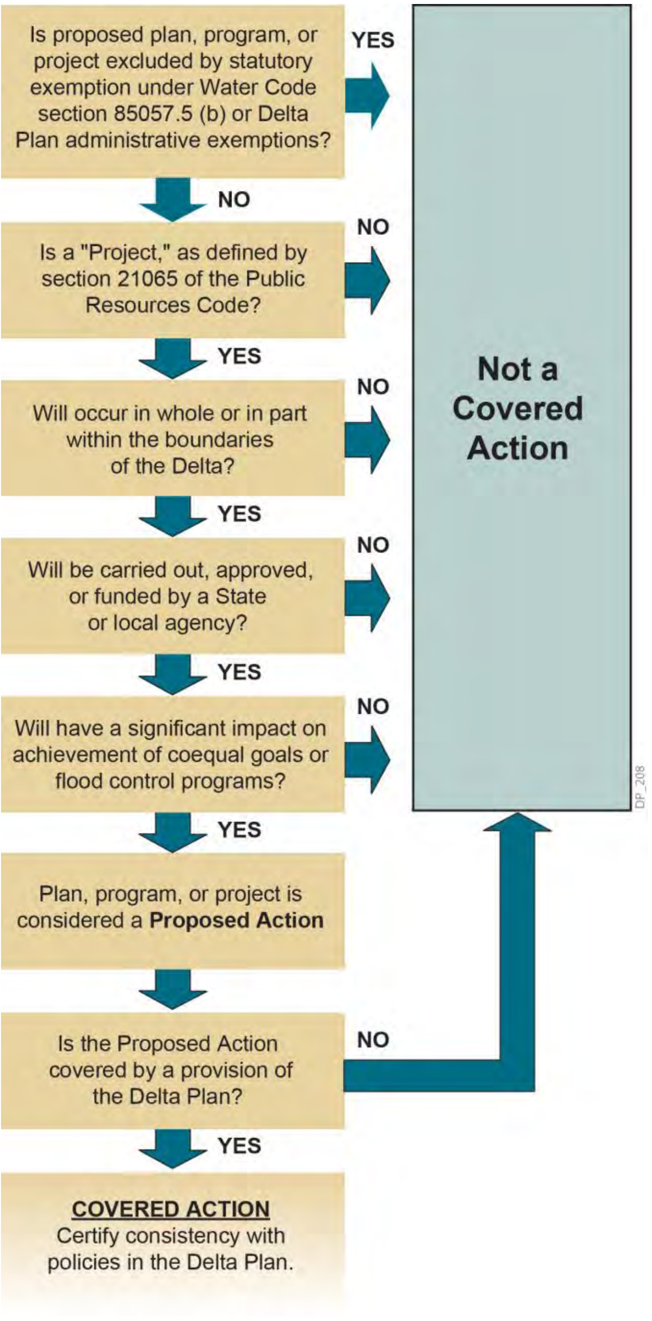
Decision Tree for State and Local Agencies on Possible Covered Actions

Figure 2-3

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[2] It is important to note that CEQA's various statutory and categorical exemptions—which are considered only after the threshold determination of a CEQA "project" is made—are not similarly incorporated by cross-reference in the definition of covered action. Therefore, the Delta Plan must expressly incorporate a CEQA exemption for it to apply to the Delta Plan.

3. **Will be carried out, approved, or funded by the State or a local public agency.** If these screening criteria are met, it is recommended that the “significant impact” criteria be analyzed next.

4. **Will have a significant impact on the achievement of one or both of the coequal goals or the implementation of a government-sponsored flood control program to reduce risks to people, property, and State interests in the Delta.** In addition, a proposed project must have a “significant impact” as defined under Water Code section 85057.5(a)(4) to qualify as a covered action. For this purpose, significant impact means a substantial positive or negative impact on the achievement of one or both of the coequal goals or the implementation of a government-sponsored flood control program to reduce risks to people, property, and State interests in the Delta, that is directly or indirectly caused by a project on its own or when the project’s incremental effect is considered together with the impacts of other closely related past, present, or reasonably foreseeable future projects. The coequal goals and government-sponsored flood control programs are further defined in Chapters 3, 4, and 7.

The following categories of projects will not have a significant impact for this purpose:

- “Ministerial” projects exempted from CEQA, pursuant to Public Resources Code section 21080(b)(1);
- “Emergency” projects exempted from CEQA, pursuant to Public Resources Code section 21080(b)(2) through (4);
- Temporary water transfers of up to 1 year in duration. This provision shall remain in effect only through December 31, 2016, and as of January 1, 2017, is repealed, unless the Council acts to extend the provision prior to that date. The Council contemplates that any extension would be based upon DWR and the SWRCB’s participation with stakeholders to identify and implement transfer measures, as recommended in WR R15;
- Other projects exempted from CEQA, unless there are unusual circumstances indicating a reasonable possibility that the project will have a significant impact under Water Code section 85057.5(a)(4). Examples of unusual circumstances could arise in connection with, among other things:
    - Local government general plan amendments for the purpose of achieving consistency with the DPC’s Land Use and Resource Management Plan; and
    - Small-scale habitat restoration projects, as referred to in CEQA Guidelines, section 15333 of Title 14 of the California Administrative Code, proposed in important restoration areas, but which are inconsistent with the Delta Plan’s policy related to appropriate habitat restoration for a given land elevation.

WHAT DOES CEQA CONSIDER A “PROJECT”?

Public Resources Code section 21065 (which is incorporated by reference in the Delta Reform Act) defines the term “project” in the following manner:

> *21065. “Project” means an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and which is any of the following:*
>
> *(a) An activity directly undertaken by any public agency.*
>
> *(b) An activity undertaken by a person which is supported, in whole or in part, through contracts, grants, subsidies, loans, or other forms of assistance from one or more public agencies.*
>
> *(c) An activity that involves the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies.*

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The Council will consider, as part of its ongoing adaptive management of the Delta Plan, whether these exemptions remain appropriate and/or whether the Delta Plan should be amended to include other types of projects.

If the above four screening criteria are met, then for purposes of the Delta Plan, the plan, program, or project is referred to as a "proposed action." Although a proposed action meets the first four screening criteria, the action has not yet been reviewed by the State or local agency to determine whether it meets the fifth screening criterion: is the proposed action covered by one or more Delta Plan policies? If the proposed action is covered by at least one Delta Plan regulatory policy, then the proposed action is a "covered action." If the proposed action is not covered by any Delta Plan regulatory policy, it is not a covered action.

5. **Is covered by one or more provisions of the Delta Plan.** This means that the proposed action must be covered by one or more regulatory policies contained in Chapters 3 through 7 of the Delta Plan. Each of those regulatory policies specifies the types of proposed actions that they cover. If the proposed action is covered by one or more provisions of the Delta Plan—the final criteria—the proposed action is, therefore, a covered action.

Statutory Exemptions

Certain actions are statutorily excluded from the definition of covered action and are exempt from the Council's regulatory authority (Water Code section 85057.5(b)). A complete list is included in Appendix F. These exemptions include:

- A regulatory action of a State agency (such as the adoption of a water quality control plan by the SWRCB, or the issuance of a California Endangered Species Act take permit by DFW)
- Routine maintenance and operation of the State Water Project or the Central Valley Project
- Routine maintenance and operation of any facility located, in whole or in part, in the Delta, that is owned or operated by a local public agency (such as routine maintenance of levees by a reclamation district)

Although a regulatory action by another State agency is not a covered action, the underlying action regulated by that agency can be a covered action (provided it otherwise meets the definition). The Council has concurrent jurisdiction over covered actions when that action is also regulated by another State agency. For example, the issuance of a California Endangered Species Act take permit by DFW is a regulatory action of a State agency and, therefore, is not a covered action. However, the underlying action requiring the take permit could be a covered action, and, if it is, it must be consistent with the Delta Plan's policies. Therefore, even when a covered action is regulated by another agency (or agencies), the covered action still must be consistent with the Delta Plan. In the situation where a covered action is governed by multiple agencies and laws, the action must comply with all relevant legal requirements.

Who Determines Whether a Proposed Plan, Program, or Project Is a Covered Action?

A State or local agency that proposes to carry out, approve, or fund a plan, program, or project is the entity that must determine whether that plan, program, or project is a covered action. That determination must be reasonable, made in good faith, and consistent with the Delta Reform Act and relevant provisions of this Plan. If requested, Council staff will meet with an agency's staff during early consultation to review consistency with the Delta Plan and to offer advice as to whether the proposed plan, program, or project appears to be a covered action, provided that the ultimate determination in this regard must be made by the agency. If an agency determines that a proposed plan, program, or project is not a covered action, that determination is not subject to Council regulatory review, but is subject to judicial review as to whether it was reasonable, made in good faith, and is consistent with the Delta Reform Act and relevant provisions of this Plan.

Mitigation of Significant Adverse Impacts on the Environment

Public Resources Code section 21081.6 requires a public agency to adopt a mitigation monitoring or reporting program (MMRP) to ensure compliance with the mitigation measures adopted by the agency at the time of project approval. The MMRP is a working implementation document to ensure that mitigation measures are implemented. The MMRP for the *Delta Plan Program Environmental Impact Report* (PEIR) ensures compliance with the Delta Plan mitigation measures. The Delta Plan MMRP lists the mitigation measures incorporated into the Delta Plan, when they need to be implemented, who is responsible for implementing them, and who reports on compliance. As specified in policy G P1 of the Delta Plan, any covered action that is not exempt must include either the mitigation measures identified in the Delta Plan's PEIR, if applicable and feasible; substitute mitigation measures that the proposing agency finds to be equally or more effective than those identified in the Delta Plan PEIR; or an explanation of why such mitigation is not feasible. Monitoring and/or reporting on implementation of the adopted Delta Plan mitigation measures will be accomplished through the certification of consistency process as part of the certification forms. The MMRP can be found on the DSC's website at http://deltacouncil.ca.gov/.

Certifications of Consistency

Once a State or local agency has determined that their plan, program, or project is a covered action under the Delta Plan, they are required to submit a written certification to the Council, with detailed findings, demonstrating that the covered action is consistent with the Delta Plan (Water Code section 85225 et seq.). Furthermore:

- The first policy in the Delta Plan, G P1, describes requirements to be included in the certification of consistency for all covered actions and is included in this chapter.
- The certification of consistency must be submitted to the Council prior to initiating implementation of the covered action.
- The certification of consistency should not be submitted to the Council until the covered action has been fully described and the impacts associated with the covered action have been identified; this coincides with the completion of the CEQA process.
- Should the covered action project change substantially, the agency will be required to submit a new certification of consistency to the Council.

The Council has developed a discretionary checklist that agencies may use to facilitate the process, as well as certification forms and related materials, available on the Council website.

Bay Delta Conservation Plan Covered Activity Consistency Certification

The Delta Reform Act describes a specific process for the potential incorporation of BDCP into the Delta Plan. If BDCP is incorporated, an agency proposing a qualifying "covered activity" under BDCP that also meets the statutory definition of a covered action must file a short form certification of consistency with findings indicating only that the covered action is consistent with the BDCP. Consistency for these purposes shall be presumed if the certification filed by the agency includes a statement to that effect from DFW.

Covered Action Consistency Appeals

In contrast to how many other governmental plans are implemented, the Council does *not* exercise direct review and approval authority over covered actions to determine their consistency with the regulatory policies in the Delta Plan. Instead, State or local agencies self-certify Delta Plan consistency, and the Council serves as an appellate body for those determinations.

Any person, including any member of the Council or its Executive Officer, who claims that a covered action is inconsistent with the Delta Plan and, as a result of that inconsistency, will have a significant adverse impact on the achievement of one or both of the coequal goals or implementation of government-sponsored flood control program, may file an appeal with regard to a certification of consistency submitted to Council.

The Council has appellate authority to determine the consistency of covered actions with the Delta Plan if they are challenged. The Council is required to apply the standard of substantial evidence when reviewing covered action appeals. State or local agencies are required to submit detailed findings upon filing their consistency determination, described previously. These findings and the record will provide the basis for the Council's decision making.

Per statute, an appeal must be filed within 30 days; if a valid appeal is filed, the Council is responsible for subsequent evaluation and determination—as provided in statute and the Council's Administrative Procedures Governing Appeals—of whether the covered action is consistent with the Delta Plan's policies. More than one policy in the Delta Plan may apply to a covered action. If no person appeals the certification of consistency, the State or local public agency may proceed to implement the covered action.

In the event of an appeal of a covered action, the Council may consult with the DPC consistent with Public Resources Code section 29773.

Upon receiving an appeal, the Council has 60 days to hear the appeal and an additional 60 days to make its decision and issue specific written findings. If the covered action is found to be inconsistent, the project may not proceed until it is revised so that it is consistent with the Delta Plan.

The appeals process is described in statute and further defined in the appeals procedures adopted by the Council; it is attached for reference purposes as Appendix D.

POLICIES AND RECOMMENDATIONS

State and local agencies approve many important plans, programs, and projects annually that are in or otherwise affect the Delta. Interagency coordination is often limited and, despite the Delta's special status, there are no overarching guidelines or coordinated best management practices to ensure that all significant actions use best available science or adaptive management in particular. The Delta Reform Act, in describing a process for coordinating actions under the Delta Plan, requires that State or local government actions are consistent with the Delta Plan and supported by detailed findings. Policy G P1 describes compliance requirements for covered actions that are to be included in the project proponent's written findings.

Problem Statement

Independent and disparate actions by individual agencies can lead to conflict and reduce successful achievement of the coequal goals. Lack of uniform use of best available science and adaptive management for water supply and ecosystem projects can lead to unintended consequences, reduced likelihood of project success, and increased likelihood of adverse environmental impacts. In addition, management actions can be delayed when uncertainty exists, while adaptive management allows for flexible decision making despite uncertainty.

In some cases, project proponents do not carefully plan for the resources and costs of monitoring and tracking, and full adaptive management does not occur. Failure of significant Delta-related actions to comply with existing law can thwart the successful achievement of the coequal goals.

Policies

The appendices referred to in the policy language below are included in Appendix B of the Delta Plan.

G P1. Detailed Findings to Establish Consistency with the Delta Plan

(a) This policy specifies what must be addressed in a certification of consistency filed by a State or local public agency with regard to a covered action. This policy only applies after a "proposed action" has been determined by a State or local public agency to be a covered action because it is covered by one or more of the policies contained in Article 3. Inconsistency with this policy may be the basis for an appeal.

(b) Certifications of consistency must include detailed findings that address each of the following requirements:

(1) Covered actions, in order to be consistent with the Delta Plan, must be consistent with this regulatory policy and with each of the regulatory policies contained in Article 3 implicated by the covered action. The Delta Stewardship Council acknowledges that in some cases, based upon the nature of the covered action, full consistency with all relevant regulatory policies may not be feasible. In those cases, the agency that files the certification of consistency may nevertheless determine that the covered action is consistent with the Delta Plan because, on whole, that action is consistent with the coequal goals. That determination must include a clear identification of areas where consistency with relevant regulatory policies is not feasible, an explanation of the reasons why it is not feasible, and an explanation of how the covered action nevertheless, on whole, is consistent with the coequal goals. That determination is subject to review by the Delta Stewardship Council on appeal;

(2) Covered actions not exempt from CEQA must include applicable feasible mitigation measures identified in the Delta Plan's Program EIR (unless the measure(s) are within the exclusive jurisdiction of an agency other than the agency that files the certification of consistency), or substitute mitigation measures that the agency that files the certification of consistency finds are equally or more effective;

(3) As relevant to the purpose and nature of the project, all covered actions must document use of best available science;

(4) Ecosystem restoration and water management covered actions must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management. This requirement shall be satisfied through both of the following:

(A) An adaptive management plan that describes the approach to be taken consistent with the adaptive management framework in Appendix 1B, and

(B) Documentation of access to adequate resources and delineated authority by the entity responsible for the implementation of the proposed adaptive management process.

(c) A conservation measure proposed to be implemented pursuant to a natural community conservation plan or a habitat conservation plan that was:

(1) Developed by a local government in the Delta; and

(2) Approved and permitted by the California Department of Fish and Wildlife prior to May 16, 2013

is deemed to be consistent with sections 5005 through 5009 of this Chapter if the certification of consistency filed with regard to the conservation measure includes a statement confirming the nature of the conservation measure from the California Department of Fish and Wildlife.

23 CCR Section 5002
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85225, 85225.10, 85020, 85054, 85302(g), and 85308, Water Code.

Problem Statement

Currently, science efforts related to the Delta are performed by multiple entities with multiple agendas and without an overarching plan for coordinating data management and information sharing among entities. Increasingly, resource management decisions are made in the courtroom as conflicting science thwarts decision making and delays action. Multiple frameworks for science in the Delta have been proposed, but a comprehensive science plan that organizes and integrates ongoing scientific research, monitoring, analysis, and data management among entities has yet to be fully formulated.

Recommendations

G R1. Development of a Delta Science Plan

The Delta Stewardship Council's Delta Science Program should develop a Delta Science Plan by December 31, 2013. The Delta Science Program should work with the Interagency Ecological Program, Bay Delta Conservation Plan, California Department of Fish and Wildlife, and other agencies to develop the Delta Science Plan. To ensure that best science is used to develop the Delta Science Plan, the Delta Independent Science Board should review the draft Delta Science Plan.

The Delta Science Plan should address the following:

- *A collaborative institutional and organizational structure for conducting science in the Delta*
- *Data management, synthesis, scientific exchange, and communication strategies to support adaptive management and improve the accessibility of information*
- *Strategies for addressing uncertainty and conflicting scientific information*
- *Prioritization of research and balancing of the short-term immediate science needs with science that enhances comprehensive understanding of the Delta system over the long term*
- *Identification of existing and future needs for refining and developing numerical and simulation models along with enhancing existing Delta conceptual models (e.g., the Interagency Ecological Program (IEP) Pelagic Organism Decline (POD) and the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) models)*
- *An integrated approach for monitoring that incorporates existing and future monitoring efforts*
- *An assessment of financial needs and funding sources to support science*

Timeline for Implementing Policies and Recommendations

Figure 2-4 lays out a timeline for implementing the policies and recommendations described in the previous section. The timeline emphasizes near-term and intermediate-term actions.

Timeline for Implementing Policies and Recommendations

TIMELINE

CHAPTER 2: The Delta Plan

	ACTION (REFERENCE #)	LEAD AGENCY(IES)	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025
POLICIES	Detailed findings to establish consistency with the Delta Plan (G P1)	Varies	●	●
RECOMMENDATIONS	Development of a Delta Science Plan (G R1)	Council	●	
COUNCIL ACTIONS	Establish Delta Plan Interagency Implementation Committee	Council	●	●

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Agency Key:
Council: Delta Stewardship Council

Figure 2-4

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CHAPTER 3

A More Reliable Water Supply for California




ABOUT THIS CHAPTER

This chapter provides an overview of California's water supply, where it comes from, and how it is used. It also describes California's water policy foundations, including federal, State of California (State), and local policies, laws, and programs, and the need for continued improvements in local water planning, management, and information. It explains the special role of the Sacramento-San Joaquin Delta (Delta) in California's water, including its history, conflicts and challenges, and necessary investments and changes to achieve flexibility, improve resiliency, and increase water supply reliability.

As a starting point for this Delta Plan, four core water strategies must be implemented throughout the state to achieve the coequal goal of providing a more reliable water supply for California:

- Increase water conservation and expand local and regional supplies
- Improve groundwater management
- Improve conveyance and expand storage
- Improve water management information

These core strategies form the basis of the 2 policies and 19 recommendations found at the end of the chapter.

RELEVANT LEGISLATION

The Sacramento-San Joaquin Delta Reform Act of 2009 declares State policy for California's water resources and the Delta (Water Code section 85054):

> *"Coequal goals" means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.*

The Legislature declares the following objectives inherent in the coequal goals for management of the Delta (Water Code section 85020):

> *(a) Manage the Delta's water and environmental resources and the water resources of the State over the long term.*
>
> *(d) Promote statewide water conservation, water use efficiency, and sustainable water use.*
>
> *(f) Improve the water conveyance system and expand statewide water storage.*

The Legislature declared that:

> *85004(b) Providing a more reliable water supply for the state involves implementation of water use efficiency and conservation projects, wastewater reclamation projects, desalination, and new and improved infrastructure, including water storage and Delta conveyance facilities.*

Reduced reliance on the Delta for water supplies is established as State policy, along with an associated mandate for regional self-reliance (Water Code section 85021):

> *The policy of the State of California is to reduce reliance on the Delta in meeting California's future water supply needs through a statewide strategy of investing in improved regional supplies, conservation, and water use efficiency. Each region that depends on water from the Delta watershed shall improve its regional self-reliance for water through investment in water use efficiency, water recycling, advanced water technologies, local and regional water supply projects, and improved regional coordination of local and regional water supply efforts.*

Water Code sections 85302, 85303, 85304, and 85211 provide direction on measures that must be included in the Delta Plan to meet the statewide water supply policy goals and objectives, and ultimately the coequal goal of increased water supply reliability:

> *85302(d) The Delta Plan shall include measures to promote a more reliable water supply that address all of the following:*
>
> > *(1) Meeting the needs for reasonable and beneficial uses of water.*
> >
> > *(2) Sustaining the economic vitality of the State.*
> >
> > *(3) Improving water quality to protect human health and the environment.*
>
> *85303 The Delta Plan shall promote statewide water conservation, water use efficiency, and sustainable use of water.*
>
> *85304 The Delta Plan shall promote options for new and improved infrastructure relating to the water conveyance in the Delta, storage systems, and for the operation of both to achieve the coequal goals.*
>
> *85211 The Delta Plan shall include performance measurements that will enable the council to track progress in meeting the objectives of the Delta Plan. The performance measurements shall include, but need not be limited to, quantitative or otherwise measurable assessments of the status and trends...*
>
> > *(b) The reliability of California water supply imported from the Sacramento River or the San Joaquin River watershed.*

The longstanding constitutional principle of reasonable use and the Public Trust Doctrine form the foundation of California's water management policy, and are particularly applicable to the Delta watershed and to the others areas that use Delta water as the basis for resolving water conflicts (Water Code section 85023). The constitutional principle is defined in Section 2 of Article X of the California Constitution as:

> *The right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water.*

Water Code sections 85031 and 85032 provide clarification that existing water rights, procedures, or laws are not affected:

> *85031(a) This division does not diminish, impair, or otherwise affect in any manner whatsoever any area of origin, watershed of origin, county of origin, or any other water rights protections, including, but not limited to, rights to water appropriated prior to December 19, 1914, provided under the law. This division does not limit or otherwise affect the application of Article 1.7 (commencing with Section 1215) of Chapter 1 of Part 2 of Division 2, Sections 10505, 10505.5, 11128, 11460, 11461, 11462, and 11463, and Sections 12200 to 12220, inclusive.*
>
> > *(b) For the purposes of this division, an area that utilizes water that has been diverted and conveyed from the Sacramento River hydrologic region, for use outside the Sacramento River hydrologic region or the Delta, shall not be deemed to be immediately adjacent thereto or capable of being conveniently supplied with water therefrom by virtue or on account of the diversion and conveyance of that water through facilities that may be constructed for that purpose after January 1, 2010.*
> >
> > *(c) Nothing in this division supersedes, limits, or otherwise modifies the applicability of Chapter 10 (commencing with Section 1700) of Part 2 of Division 2, including petitions related to any new conveyance constructed or operated in accordance with Chapter 2 (commencing with Section 85320) of Part 4 of Division 35.*
> >
> > *(d) Unless otherwise expressly provided, nothing in this division supersedes, reduces, or otherwise affects existing legal protections, both procedural and substantive, relating to the state board's regulation of diversion and use of water, including, but not limited to, water right priorities, the protection provided to municipal interests by Sections 106 and 106.5, and changes in water rights. Nothing in this division expands or otherwise alters the board's existing authority to regulate the diversion and use of water or the courts' existing concurrent jurisdiction over California water rights.*
>
> *85032 This division does not affect any of the following:*
>
> > *(a) The Natural Community Conservation Planning Act (Chapter 10 (commencing with Section 2800) of Division 3 of the Fish and Game Code).*
> >
> > *(b) The California Endangered Species Act (Chapter 1.5 (commencing with Section 2050) of Division 3 of the Fish and Game Code).*
> >
> > *(c) The Fish and Game Code.*
> >
> > *(d) The Porter-Cologne Water Quality Control Act (Division 7 (commencing with Section 13000).*
> >
> > *(e) Chapter 8 (commencing with Section 12930) of Part 6 of Division 6.*
> >
> > *(f) The California Environmental Quality Act (Division 13 (commencing with Section 21000) of the Public Resources Code).*
> >
> > *(g) Section 1702.*
> >
> > *(h) The application of the public trust doctrine.*
> >
> > *(i) Any water right.*
> >
> > *(j) The liability of the state for flood protection in the Delta or its watershed.*

CHAPTER 3

A More Reliable Water Supply for California

In California, the conflicts over water are legendary. The connotations of wealth and power associated with control over water were captured in dramatic fashion in the 1974 film *Chinatown*. A decade later, Marc Reisner's bestselling nonfiction book, *Cadillac Desert*, described vast, arid California land tracts turned to lush, productive fields through the modern magic of water diversion and irrigation. California is known for many things: the urban, cultural giant that is Los Angeles; the great Central Valley, breadbasket to the world; cutting-edge technological advances hailing from Silicon Valley; and the fertile human-made islands of the Delta. The thread that ties these places together is a supply of fresh water from the Sacramento-San Joaquin watershed. Similarly, dozens of fish species—some of them threatened by extinction—and a diverse palette of flora and fauna also depend on this water. As described in Chapter 1, at the heart of California's water troubles are scarcity of supply and competing uses—in particular, conflict with the water needs of the ecosystem. This dynamic of conflict characterizes the essential debate over management of the Delta.

Building on the foundations of California water policy, the Delta Reform Act established the goal of providing "a more reliable water supply for California." This is coequal with the goal of "protecting, restoring, and enhancing the Delta ecosystem." Both must be accomplished while protecting and enhancing the unique values of the Delta as an evolving place. (See sidebar, What Does It Mean to Achieve the Goal of Providing a More Reliable Water Supply for California?)

The Delta Reform Act recognizes that the "Delta watershed and California's water infrastructure are in crisis and existing Delta policies are not sustainable" (Water Code section 85001(a)). The economies of major regions of the state are reliant upon the ability to use water within the Delta watershed or on water imported from the Delta watershed. Yet, the long-term impacts of these diversions, on the Delta and its watershed, in combination with many other factors, are causing native fisheries to decline. In recent years, the populations of salmon and several other fish species have reached their lowest numbers in recorded history, and many of California's salmon runs are now listed as endangered by the State or federal government. The courts have responded by imposing constraints, particularly in dry years, on water diversions through the Delta. As a result, water deliveries—particularly those that come from the State Water Project (SWP) and the federal Central Valley Project (CVP)—have become increasingly unpredictable.

The Delta Reform Act mandates many strategies that the Delta Plan must address to improve water supply reliability for California:[1]

- Promote, implement, and invest in water efficiency and conservation
- Implement and invest in wastewater reclamation and water recycling
- Increase and invest in desalination and advanced water treatment technologies
- Promote and implement options for improved water conveyance

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[1] See Water Code sections 85004(b), 85020(d) and (f), 85021, 85023, 85302(d), 85303, and 85304.

- Expand and invest in storage
- Improve water quality to protect human health and the environment
- Invest in local and regional water supply projects and coordination
- Prohibit waste and unreasonable use, consistent with Article X, Section 2 of the California Constitution, and protect public trust resources consistent with the Public Trust Doctrine

California's precipitation is extremely variable, and both droughts and floods are not uncommon, even occurring in back-to-back years. Therefore, the State must adapt its water infrastructure and operations in the Delta to make better use of the greater volumes of water that are and, in the future, will continue to be available during wet years, and to take less water during dry years when conflicts with the Delta ecosystem and in-Delta water quality are at their greatest. Concurrently, the development and careful management of local water resources hold tremendous potential for improving water reliability and must be a priority for California.

Management of any natural resource is a continual balancing act. Establishment of the coequal goals provides policy priorities when it comes to managing water, but continuing disputes are inevitable. Given that water in California is scarce, actions that occur in one corner of the state can have ripple effects hundreds of miles away. Levee failures in the Delta may interrupt water supplies to industry in San Diego. Conversely, the way Southern California regions manage their water may affect California's water-dependent ecosystems. The management of a salinity regime to benefit the environment has implications for in-Delta water users. Upstream water use can affect the quality and quantity of water for all downstream users—urban, agricultural, or environmental. Decades-old decisions to drain swamps, build intrastate water projects, and mine gold have left legacy imprints on California's water and ecosystem management.

Although exports from the Delta account for only a fraction of California's water supplies, the Delta is of widespread importance given its geographic location and influential role in ecosystem dynamics. Those who live in the Delta watershed are concerned about how management actions in the Delta may affect them; those who live in the Delta are keenly aware of others' interest in their backyard; and those who rely fully or partially on Delta exports, in some cases located hundreds of miles from the Delta itself, fear the impacts of reduced water supply reliability on their local economies and standard of living.

The broad influence of the Delta is precisely why the Delta crisis cannot be resolved by taking actions in the Delta alone. The Delta Reform Act establishes a new policy for California of reducing "reliance on the Delta in meeting California's future water supply needs" (Water Code section 85021). Reduced reliance is to be achieved through a statewide strategy of investing in improved local and regional supplies, conservation, and water use efficiency so that "each region that depends on water from the Delta watershed shall improve its regional self-reliance." The State's water planning document, the *California Water Plan – Update 2009*, estimates that California could reduce water demand and increase water supply in the range of 5 to 10 million acre-feet (MAF) by 2030 just through the implementation of existing strategies and technology (DWR 2009). This amount of water is more than enough to meet the projected water demands of California's growing population through 2050. An integrated approach that includes increased water efficiency, local and regional diversification of water supplies, reduced reliance on water from the Delta, improved regional self-reliance, and concurrent improvements to storage and Delta infrastructure will build the resiliency and reliability of California's water supply.

WHAT DOES IT MEAN TO ACHIEVE THE GOAL OF PROVIDING A MORE RELIABLE WATER SUPPLY FOR CALIFORNIA?

Achieving the coequal goal of providing a more reliable water supply for California means better matching the state's demands for reasonable and beneficial uses of water to the available water supply.

- This will be done by promoting, improving, investing in, and implementing projects and programs that improve the resiliency of the state's water systems, increase water efficiency and conservation, increase water recycling and use of advanced water technologies, improve groundwater management, expand storage, and improve Delta conveyance and operations. The evaluation of progress toward improving reliability will take into account the inherent variability in water demands and supplies across California.

Regions that use water from the Delta watershed will reduce their reliance on this water for reasonable and beneficial uses, and improve regional self-reliance, consistent with existing water rights and the State's area of origin statutes and Reasonable Use and Public Trust Doctrines.

- This will be done by improving, investing in, and implementing local projects and programs that increase water conservation and efficiency, increase water recycling and use of advanced water technologies, expand storage, improve groundwater management, and enhance regional coordination of local and regional water supply development efforts.

Water exported from the Delta will more closely match water supplies available to be exported, based on water year type and consistent with the coequal goal of protecting, restoring, and enhancing the Delta ecosystem.

- This will be done by improving conveyance in the Delta and expanding groundwater and surface storage both north and south of the Delta to optimize diversions in wet years when more water is available and conflicts with the ecosystem less likely, and limit diversions in dry years when conflicts with the ecosystem are more likely. Delta water that is stored in wet years will be available for water users during dry years, when the limited amount of available water must remain in the Delta, making water deliveries more predictable and reliable. In addition, these improvements will decrease the vulnerability of Delta water supplies to disruption by natural disasters, such as earthquakes, floods, and levee failures.

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Accordingly, the Delta Stewardship Council (Council) envisions a future in which California has achieved the coequal goal of improved water supply reliability. In the future:

- California's water resources will be better managed, consistent with the State's Reasonable Use and Public Trust Doctrines.
- Improved efficiency and a greater diversity of sources will make more water available to meet the state's demands.
- Groundwater resources will be sustainably managed, and critical overdraft in groundwater basins will have been eliminated.
- Water suppliers in regions that use water from the Delta watershed will have reduced their reliance on this water and improved their regional self-reliance. California will be better prepared to meet the challenges of climate change and catastrophic events that may affect future water deliveries.

In the future, water exports from the Delta will more closely match water supplies available to be exported, consistent with California's variable hydrology and the coequal goal of protecting, restoring, and enhancing the Delta ecosystem. Conveyance facilities in the Delta will be improved, and additional groundwater and surface storage, both north and south of the Delta, will help optimize diversions in wet years when more water is available and conflicts with the ecosystem are less likely, and limit diversions in dry years when conflicts with the ecosystem are more likely. These patterns of Delta exports will be consistent with more natural flow patterns in the Delta, which will aid native species and reduce regulatory uncertainty. At the same time, deliveries of Delta water will be more predictable due to use of storage to deliver wet-year water that is exported and stored for future use. Flexibility of export operations will be enhanced through implementation of local and regional water efficiency, improved conveyance to reduce conflicts with the ecosystem, and water supply projects that reduce pressure on the Delta and reliance on these deliveries.

California's Water Supply Picture

California's water supply picture makes it unlike any other state in the nation. Geography, hydrology, circumstance, and governance have shaped the political landscape of California water in a manner that has both intrigued and frustrated people for decades. Engineering alterations have enabled urban metropolises to thrive—and sprawl—and expansive agricultural regions with global influence to flourish with supplemental water, imported in some cases from hundreds of miles away and across county and even state boundaries. A complex and sometimes conflicting system of laws and policies means that in dry years, frequent in California, a given water district might have surplus supplies with which to grow lettuce or alfalfa, while a district next door battles drought conditions and the associated economic and environmental impacts. A growing awareness of how past water management practices have led to current environmental conflicts and overall competition for water supplies, combined with the knowledge that past climate patterns are not necessarily indicative of the next century's hydrograph, are shaping how California plans for its water future (see Figure 3-1).

This section provides an overview of where California's water comes from and how it is used, the state's vast water supply infrastructure system, and the implications of climate change on California's water supplies.

Sources of California's Water Supply

Variability and uncertainty are the dominant characteristics of California's water resources. Precipitation is the primary source of California's water supply. However, this precipitation varies greatly from year to year, as well as by season and where it falls geographically in the state, which makes management of the state's water resources complex and challenging. Groundwater, which is often connected to surface supplies, contributes to a significant portion of California's water use, on average supplying 8 MAF (20 percent) of California's urban and agricultural uses; but in some areas, this figure is considerably higher and can be as much as 60 to 80 percent of a region's water supply (DWR 2009). Groundwater, and implications for its overuse, is discussed in greater detail later in this chapter.

The total amount of precipitation in an average year provides California with about 200 MAF of surface water falling as either rain or snow (DWR 2009).[2] The actual volume of water the state receives each year varies dramatically depending on whether the year is dry or wet. California may receive less than 100 MAF of water during a dry year and more than 300 MAF in a wet year (Western Regional Climate Center 2011a).

The term "average water year" in California is useful for explanatory purposes, but can be misleading as a measurement for planning. In fact, California experiences the most unpredictable pattern of precipitation in the nation, with the bulk of its annual water falling within just 5 to 15 days (Dettinger et al. 2011). This means that in years when fewer storms pass over California, the state faces the problem of too little water; conversely, a few extra storms may result in flooding. For example, between 2005 and 2008, Los Angeles experienced both its driest and wettest years on record (California Natural Resources Agency 2008). The historical record shows that California has frequently experienced long multiyear droughts, as well as extremely wet years that coincide with substantial flooding and consequent risk to people and property (Hanak et al. 2011).

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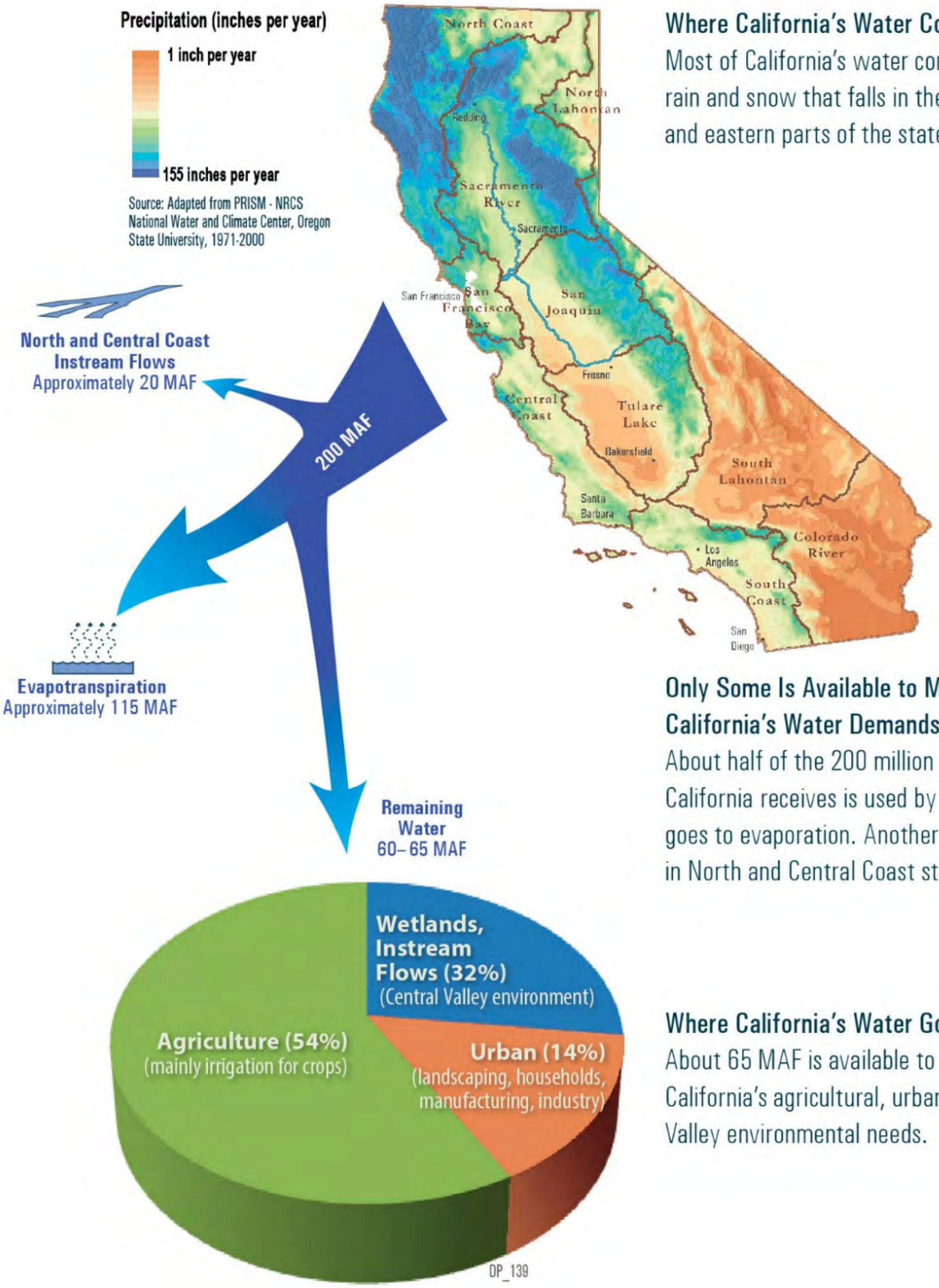
[2] Includes up to 10 MAF of precipitation that occurs in Oregon, Mexico, and the Colorado River and is imported into California.

How California's Water Is Used



Where California's Water Comes From

Most of California's water comes from rain and snow that falls in the northern and eastern parts of the state.

Only Some Is Available to Meet California's Water Demands

About half of the 200 million acre-feet (MAF) California receives is used by vegetation or goes to evaporation. Another 20 MAF stays in North and Central Coast streams.

Where California's Water Goes

About 65 MAF is available to meet California's agricultural, urban, and Central Valley environmental needs.

Figure 3-1 *Sources: Adapted from DWR 2009, USGS 2010*

Most of California's precipitation occurs between November and April, yet most of the state's agricultural and urban water demand is in the hot, dry months of summer and early fall, creating a management challenge. In addition, most of the precipitation falls in the mountains in the middle to northern half of the state, far from major population and agricultural centers. In some years, the far north of the state can receive 100 inches or more of precipitation while the southernmost regions receive only a few inches (Western Regional Climate Center 2011b). These basic characteristics of precipitation in California—seasonal timing and geography—and their fundamental disconnect with where and when Californians demand water provide the basic explanation for why water in California is such a complicated and controversial matter.

How California's Water Is Used

The amount of water available to meet agricultural, urban, and ecosystem water demands starts with the state's annual precipitation. On average, about half of this water evaporates; is used by surface vegetation for transpiration; or flows to deep subsurface areas, saline sinks, or the ocean (DWR 2009). The rest of this water—known as "dedicated water"[3]—is used to supply urban municipal and industrial uses, agricultural irrigation, water for ecosystem protection and restoration, and for storage in surface and groundwater reservoirs (DWR 2009).

Patterns of how and when water is used in the state vary with the type of water year. In fact, although best available estimates are included in this Delta Plan, state water managers often work with limited or incomplete information related to water use. The California Department of Water Resources (DWR) uses five water year–type classifications for planning and management purposes: wet, above normal, below normal, dry, and critically dry. In wet years, due to plentiful local rainfall, agricultural and urban landscape irrigation water demands are generally lower. Water demands are usually highest in years of reduced rainfall and because local supplies are low (DWR 2009). Ironically, agricultural and urban water demands may be lower during critically dry years because of short-term water use reduction actions, such as rationing or cropland fallowing to cope with water shortages.

In an average water year, this dedicated water totals approximately 80 to 85 MAF.[4] Again, the fluctuations between wet and dry years can be extreme, with wet years providing more than 95 MAF and critically dry years producing less than 65 MAF of available supply (LAO 2008, DWR 2009, USGS 2010).

However, not all of the 80 to 85 MAF is available to meet water demands within the Central Valley, Bay Area, and Southern California. In the late 1970s, the California Legislature secured State and federal protection of California's North Coast rivers and, in doing so, precluded major diversions from these rivers, including parts of the Trinity, Scott, Salmon, Eel, and Klamath rivers. Water from these rivers is now largely mandated to the environment by law, with the exception of diversions from the Trinity River to the Sacramento River for CVP supplies that are limited by federal law (Hanak et al. 2011). As a result, in an average year, approximately 20 MAF (out of the available supply of 80 to 85 MAF) are reserved for Wild and Scenic Rivers and other instream flow requirements in the North Coast and San Francisco Bay regions and some Central Coast and South Coast areas. Most of this water falls outside the Delta watershed. Although original State water plans and State and federal water contracts envisioned its capture and conveyance, permanent legal protections now prohibit it. (See the CVP and SWP Water Delivery Challenges section.)

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[3] DWR uses the terms "dedicated" and "developed" interchangeably in their publications. DWR identifies California's average annual dedicated water supply as 85 MAF.

[4] All statewide average water use values were calculated using information in Volume 5 DWR Water Plan 2009 (including average values for years 1998 through 2005) and results from CALSIM II model runs prepared for DWR State Water Project Reliability Studies (DWR 2010b, DWR 2011c).

This means that the remaining water supply (of 60 to 65 MAF in an average year) goes to meet agricultural and urban demands and Central Valley environmental needs.[5,6] In an average year, irrigated agriculture uses approximately 34 MAF (54 percent) of this water, urban areas use about 9 MAF (14 percent), and 20 MAF (32 percent) is mandated to meet instream flow requirements, including State Water Resources Control Board (SWRCB) Delta water quality requirements and Central Valley wildlife refuge commitments (DWR 2009).

Accounting for how much water each sector actually uses is complicated because water may be reused several times for different purposes or it may be taken from surface or groundwater storage held from previous years.[7] The lack of consistent and accurate estimates of statewide water use is a significant challenge that has important implications for improved water management in California.

Future population and economic growth is expected to result in increased water demand. Today, California's water supply supports a population of 36.5 million people, an economy of $1.9 trillion, and diverse natural resources (LAO 2011). The largest economic sectors in the state are trade, transportation, and financial services, with agricultural services contributing about $38 billion (2 percent). Projections by the California Department of Finance in 2010 forecast that the population may grow to 60 million people by 2050, but the rate of growth is slowing and could be much lower.[8] As more development occurs, water use will continue to shift away from agricultural toward urban uses (DWR 2005, DWR 2009, LAO 2008, Hanak et al. 2011). At the same time, increasing water needs for ecosystem protection will likely exacerbate conflicts with agricultural and urban water demands.

California's Water Supply Infrastructure

To provide more reliable water supplies despite the state's hydrologic variability and diverse geography, and also to manage floods during wet years, State, federal, and local agencies have built a vast, interconnected infrastructure system throughout California (see Figure 3-2). The Delta, because of its geographic location and role in conveying water supplies, is often described as the "linchpin" of California's water infrastructure. Rivers and dredged channels act as conveyance canals, and pumping plants provide the momentum to move stored water to areas south. California's overall system includes a range of surface reservoirs, aqueducts, pumping plants, operable gates, groundwater wells, and water treatment facilities constructed over the last hundred plus years.

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[5] Data are from 2000, which DWR categorized as an "average" rainfall year for the state.

[6] The "remaining water" of approximately 60 to 65 MAF, (62.4 MAF for purposes of percentage calculations) is referred to throughout this chapter as "total water use," unless otherwise specified. Total water use includes urban, agricultural, and Central Valley environmental uses such as instream flow requirements and non-CVP-managed wetlands.

[7] For example, water that is dedicated to instream flows often becomes available for downstream diversion to agricultural and urban uses. Some portion of the water that is used for agricultural irrigation or drinking water is returned to the ecosystem through agricultural tailwater releases, infiltration of irrigation water into groundwater, and discharges from sewage treatment plants. The State does not have a system for documenting these multiple uses.

[8] Growth projections by the California Department of Finance are regularly revised and over the past 2 decades reflect a trend toward slower expected growth for the state. Between 1993 and 2004, the California Department of Finance's population projections for 2040 declined by 12 million people, from 62 million to 50 million.

Moving and Storing California's Water

Figure 3-2

Large State, federal, and local dams and canal systems play an important role in storing and conveying water throughout California to meet a variety of urban and agricultural water demands.

Source: Adapted from DWR 2009

On average, local and regional water supplies account for 52 MAF (84 percent) of the state's total water use. Of the 52 MAF, about 44 MAF (84 percent) of the water supply comes from local surface water storage and deliveries, and includes sources such as the Santa Ana, Los Angeles, and Ventura river watersheds in Southern California; local diversions from the Sacramento and San Joaquin rivers; and stream drainages in the central coastal areas. In addition, groundwater supplies about 8 MAF (13 percent) of the state's total water use in average years (20 percent of urban and agricultural water use), and during droughts, can provide up to 60 percent or more for specific regions (DWR 2009). A small but rapidly growing percentage of local water comes from recycled water and water reuse projects.

Supplemental water supplies are conveyed from wetter regions of California, primarily through diversions of runoff from the great Sierra Nevada mountain range and some water from the Trinity River in the north state. In most regions, these imported water supplies augment local and regional sources, especially in dry years and dry seasons. On average, approximately 10.1 MAF (16 percent) of the state's total water use comes through a combination of major conveyance and storage facilities from water sources within California and from other states, with the SWP and CVP making up the majority of these imports (5.1 MAF, about 8 percent), and Hetch Hetchy (0.2 MAF), Mokelumne (0.3 MAF), and the Los Angeles Aqueduct (0.2 MAF) comprising the remaining in-state imports. A significant portion of the state's water supplies are imported from outside California, primarily from the Colorado River (4.3 MAF) through the Colorado River Aqueduct, which serves agricultural and urban demand in Southern California.

The network of infrastructure to store and convey water in California is impressive by modern standards and compared to other states. The state's single largest "reservoir" is the Sierra Nevada snowpack, which holds approximately 15 MAF per year on average (DWR 2009). However, for comparison, local, State, and federal agencies in California have constructed more than 1,200 major reservoirs with a combined storage capacity of 43 MAF, about half the average annual runoff for the entire state (Hanak et al. 2011, DWR 2011a).

Most of California's largest surface storage reservoirs are owned and operated by the federal government and total approximately 17 MAF of storage capacity. The largest federal facility, part of the CVP, is Shasta Lake, which holds 4.5 MAF. The State's single largest storage facility and keystone feature of the SWP, Lake Oroville Dam on the Feather River, has a capacity of 3.5 MAF (LAO 2008). Operating with other reservoirs as a system, these multibenefit facilities reduce the potential for floods at the same time that they make water available for seasonal water agricultural and urban demand, particularly in the summer and fall. They also generate clean electricity. Although these storage facilities provide many benefits, they have also significantly altered the natural ecology of these rivers. Dams and their associated facilities can present barriers to migrating fish and reduce or eliminate downstream gravel and sediment replenishment to the detriment of native species such as salmon. Moreover, reservoir operations have significantly modified the amount and timing of instream flows, as well as water temperature, further contributing to the decline of the state's native fish and ecological resources.

Looking to the future, fewer high-yielding surface storage sites are available in the state now because most of these areas have already been developed (NRC 2012). However, there are significant opportunities throughout California to expand groundwater storage and to reoperate surface storage in conjunction with groundwater storage (also known as conjunctive management or groundwater banking) and other programs to maximize the water supply and environmental benefits of these systems.

Climate Change Complicates Management of California's Water

With climate change, the state's water supply will become even more erratic. Weather patterns are expected to become more extreme with long, multiyear droughts becoming more frequent as well as extremely wet years. Since 1906, California has seen "dry or critically dry" years one-third of the time. This trend is increasing (California Data Exchange Center 2011).

By 2050, temperature increases of 1 to 3 degrees Celsius are expected to cause more winter precipitation to fall as rain, as opposed to snow, and to reduce the Sierra Nevada snowpack (the source of much of California's runoff) by 25 to 40 percent (DWR 2010d). Runoff patterns will shift, leading to greater cool-season runoff and decreased warm-season runoff (Reclamation 2011a). The pattern of spring runoff is also expected to change, with a more rapid spring snowmelt leading to a shorter, more intense spring period of river flow and freshwater discharge accompanied by higher flooding risks (Knowles and Cayan 2004, Knowles et al. 2006, Null et al. 2010, Willis et al. 2011). Because the Delta watershed provides a portion of the water supply for approximately 27 million Californians and irrigates millions of acres of farmland, rising sea levels leading to increased salinity intrusion, along with changes in the form of precipitation and timing of snowmelt, will profoundly alter the way water is managed in California.

Specifically, an anticipated shift in runoff patterns will present a management challenge to existing reservoir operations, with large runoff events increasingly putting pressure on reservoirs managed for multiple benefits, including flood control. Reduced natural water storage in the form of snowpack will diminish statewide carryover storage capacity, making the state increasingly vulnerable during prolonged dry periods and negatively affecting water supply reliability. Sea level rise, as much as 55 inches by 2100 (OPC 2011), will result in high salinity levels in the Delta interior, which will impair water quality for agricultural and municipal uses, and change habitat for fish species. Maintaining freshwater conditions in the Delta could require unanticipated releases of water from storage, which will reduce available water supplies for fish. Rising seas also will dramatically increase the risk of catastrophic interruption of water exports as a result of levee failure and flood events, particularly in the interior Delta where substantial subsidence has already occurred. Warmer temperatures throughout the state will cause higher evaporation rates, particularly during the hot summer and early fall months, contributing to reduced streamflows, drier soils, reduced groundwater infiltration, higher losses of water from surface reservoirs, increased urban and agricultural demand for irrigation water, and more water needed for ecosystem protection (California Natural Resources Agency 2008).

The precise local impacts of climate change on regional water resources remain less certain. Many communities in the state already experience water shortages during droughts (California Environmental Protection Agency 2006, LAO 2009). Improved modeling, especially downscaling of global climate change information to regional and local levels, will help communities to evaluate the extent of their vulnerability and to develop water management strategies that will increase the resilience of their water supply systems (USEPA and DWR 2011).

Foundations of Water Policy in California

Over the past 160 years, the California water rights system has evolved into a complex mix of public and private rights and contractual obligations that were intended to create more certainty about how water is to be allocated among urban, agricultural, and environmental uses during droughts, catastrophic interruptions in water supplies, and other times of scarcity. (See sidebar, California's Complex Water Rights System.) Yet some of these rights and obligations conflict, and now, in many years, there is insufficient water in California to support them all.

California's legal system recognizes limitations on water rights based on the longstanding doctrines of Reasonable Use and Public Trust (NRC 2012). The Delta Reform Act reiterates that the principles of reasonable use and public trust "shall be the foundation of state water management policy" and that they are "particularly important and applicable to the Delta" (Water Code section 85023). The coequal goals of improving water supply reliability for the state and restoring the Delta cannot be achieved by actions in the Delta alone. Every region in California, along with the cities and farms that receive Delta water, will need to improve their management of the state's scarce water resources.

This section discusses the legal foundations for California water policy, explains the state's system of water rights, and describes new water policies and priorities, including reduced reliance on the Delta and improved regional self-reliance, established by the Delta Reform Act.

Reasonable Use and the Public Trust Doctrines

The Reasonable and Beneficial Use and Public Trust Doctrines, in combination with existing water rights and the State's area of origin statutes, have long been the legal and policy foundation for water management in California. The State's Reasonable and Beneficial Use Doctrine specifically limits all water rights and water use in California to "such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water" (California Constitution, Article X, Section 2).

The SWRCB is the primary agency responsible for ensuring that water is not wasted and that the reasonable use standard is not violated. However, DWR also shares with them the duty to "take all appropriate proceedings and actions…to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion in this state" (Water Code section 275). The SWRCB also is responsible for determining whether any water remains available in a stream or watershed for appropriation and whether the water is being fully used for "beneficial uses," consistent with State law that identifies the types of water uses that are permitted.[9] The State can review and modify existing water rights as well as consider approval of new permits and water rights to

reflect new conditions, including California statutes that require efficient water use and improved water management.

The Public Trust Doctrine provides the State with additional authority to reconsider past water allocation decisions in light of new information and changing water demands and social values, and to modify or revoke previously granted water rights if warranted. In a 1983 landmark legal decision, the California Supreme Court unanimously affirmed that the state's navigable lakes and streams are resources that are held in trust for the public and are to be protected for navigation, commerce, fishing, recreational, ecological, and other public values. The State "has an affirmative duty to take the public trust into account in the planning and allocation of water resources and to protect public trust uses whenever feasible" (*National Audubon Society v. Superior Court*, 33 Cal. 3d 419, 658 P.2d 709, 189 Cal. Rptr. 346, 1983 Cal.). This has significant implications for governance of water resources. In fact, both the Public Policy Institute of California and Appeals Court Associate Justice Ron Robie recently called for the establishment of a public trust advocate at the SWRCB to ensure that the State's duty to protect California's public trust resources is being performed adequately (Robie 2012, Hanak et al. 2011).

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[9] Beneficial uses recognized in California include domestic, fire protection, fish and wildlife, industrial, irrigation, municipal, power production, recreation, and other uses (SWRCB 2010).

CALIFORNIA'S COMPLEX WATER RIGHTS SYSTEM

Whatever the type of water right that is held by an individual, business, or public agency, no one "owns" the water they use in California (Littleworth and Garner 2007). All water within the state is held in trust for the benefit of all the people of California (Water Code sections 102, 1201). Water rights holders have the right to "take and use water, but they do not own the water and cannot waste it" (*Central and West Basin Water Replenishment District v. Southern California Water Co.* (2003) 109 Cal. App. 4th 891, 905).

Riparian Rights – Landowners who own property that abuts a natural water course are entitled to make reasonable use of water on or flowing past their property. The water must be from a natural flow (not released stored water). Water cannot be stored under a riparian right and may only be used on property that is within the drainage of the water's source. If there is not enough water in a watershed to satisfy both riparian and appropriative rights, then riparian rights must be fulfilled first. In times of shortage, riparian right holders allocate the reduced water supply by sharing the shortage among the riparian users.

Appropriative Rights – An appropriative right is typically used when the prospective water user intends to use water on nonriparian land or the water user needs to store water for later use. Pre-1914, these rights were asserted in a manner similar to the filing of a mining claim; a water user filed a public notice of his or her intent to divert water and then diverted the water for a legally recognized beneficial use such as mining, irrigation, or drinking water. In times of shortage, appropriative right holders allocate the reduced water supply among themselves under a first in time, first in right priority system. Generally, water received through appropriative rights is more predictable than riparian rights, but appropriative rights can be lost through nonuse (because beneficial use is the basis for receiving the right), and shortages are allocated based on seniority (NRC 2012). California law recognizes water conservation as a "reasonable beneficial use" so that water efficiency improvements cannot be used as a reason to reduce appropriative rights held by a water user (Water Code section 1011(a)).

CVP and SWP Contractors – The Bureau of Reclamation and DWR hold appropriative water rights for the operation of the CVP and SWP, respectively. In many instances, these project rights are junior in priority to the rights held by water users in the Delta and within the Delta watershed. This means that during droughts and other periods of water shortages, the ability of the SWP and CVP to divert water from the Delta is limited by riparian owners and by more senior appropriative water rights.

Area of Origin Laws – Several statutes provide protections to areas within the Delta and the Delta watershed where the rivers originate (Littleworth and Garner 2007). Also known as "watershed protection" statutes, these laws provide the opportunity for water users in these areas to obtain water rights with a more senior priority than the SWP and CVP contractors so that local demands might be met before water becomes available for export.

Reasonable Use and Public Trust Doctrines – The SWRCB has the authority to review and modify existing water rights as well as approve new rights. This is an important principle because it enables the State to consider what is "reasonable" based on modern societal values, the need to protect other water users, protect the environment, and prevent the waste and unreasonable use of water. This authority derives in part, from the Public Trust Doctrine, under which the State has an ongoing duty to protect the navigable waters of the state for environmental protection, fishing, navigation, and commerce; and from the Reasonable Use Doctrine of the California Constitution, a provision mandating the reasonable and beneficial use of all waters in the state (Article X, Section 2).

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California's Water Rights System and Use Reporting

California's water rights system is of great legal significance. However, our water rights system does not and cannot guarantee a supply of water that exceeds what nature provides. Nor does any individual, business, industry, or agricultural enterprise "own" the water they use.

The amount of water used in California's stream systems is not fully known because water users under pre-1914 and riparian water rights have not been required, until recently, to submit annual reports accounting for their diversions. In 2009, the State adopted statewide water diversions reporting requirements (Water Code section 5100 et seq.); and in 2010, the SWRCB adopted regulations requiring online reporting of water use by all water rights holders, including all surface and groundwater users. In addition, there is limited information available to the State on consumptive use or the number of times that water is used within a stream system.

Discussed previously, the SWRCB has the authority to determine when a river or stream has been "over-appropriated," in other words, whether the amount of water available in a stream is less than the demands placed on that water. A right to use water represents potential diversions and uses. Actual water use in many rivers and streams is frequently far less than the total volume of asserted water rights. The difference between water rights and water received can be explained by restrictions or conditions in the permits/licenses, operation restrictions on the storage and transport facilities themselves, physical and economic limitations, non-consumptive uses such as hydroelectric power generation, and the use and reuse of water.

Understanding and reconciling the human demands for water to the supply available, while providing enough water to ensure desired and legally protected environmental and water quality goals, is a difficult process. This process is nonetheless essential to achievement of the coequal goals.

The Coequal Goals and Reducing Reliance on the Delta

In 2009, California further defined its water policy priorities as they relate to the Delta, including express recognition that the Delta crisis cannot be resolved by taking action in the Delta alone. Given the interconnected nature of the Delta with the water use patterns of large parts of Northern, Central, and Southern California, the new coequal goals of statewide water supply reliability and an improved, protected, and restored Delta ecosystem will fundamentally reshape California water management over the course of this century. Achieving these coequal goals is expected to be done, in significant part, through compliance with the Delta Reform Act's various mandates and goals relating to statewide water conservation, efficiency, and sustainable use, including the State's new policy to reduce reliance on the Delta and related mandate to improve regional self-reliance.

In particular, the Delta Reform Act mandates many statewide strategies that the Delta Plan must address to achieve the coequal goals, including water efficiency and conservation; wastewater reclamation and recycling; desalination and advanced water treatment technologies; improved water conveyance, surface, and groundwater storage; improved water quality; and implementation of local and regional water supply projects (Water Code sections 85004(b), 85020(d) and (f), 85021, 85023, 85303, and 85304). These measures help achieve the requirements of Water Code section 85021, which declares that the State's policy is "to reduce reliance on the delta in meeting California's future water supply needs through a statewide strategy of investing in improved regional supplies, conservation, and water use efficiency." That section also mandates that "[e]ach region that depends on water from the delta watershed shall improve its regional self-reliance for water through investment in water use efficiency, water recycling, advanced water technologies, local and regional water supply projects, and improved regional coordination of local and regional water supply efforts."

Consequently, to achieve the statewide water supply mandates and the coequal goal of statewide water supply reliability, regions located outside the Delta also must take actions outside the Delta to increase water efficiency and develop sustainable local and regional sources of water, which will contribute to improved water supply reliability.

Individual actions by water suppliers throughout the state will be vital to success in this regard. The implementation of programs and projects that result in a significant reduction in the amount of water used, or in the percentage of water used, from the Delta watershed (evaluated at the local, regional, and statewide levels) will be the foundational measures for assessing the State's progress in achieving these policies. The baseline for this evaluation will be existing water use and supplies, as documented in the most recently adopted urban and agricultural water management plans. (See Appendix G, Achieving Reduced Reliance on the Delta and Improved Regional Self-Reliance.)

It is important to recognize that reliance on water from the Delta and the Delta watershed varies throughout California, from region to region, and supplier to supplier. (See sidebar, Reliance on the Delta Varies by Region.) Some water suppliers have greater access to alternative water supplies or have a greater ability to implement a diverse range of water efficiency and water supply projects. Others, particularly in the upper watershed, may have a narrower range of options.

The key is that every supplier is doing its part and is taking appropriate action to contribute to the achievement of the coequal goals, including the State's policy of reduced reliance and associated mandate to improve regional self-reliance.

The Delta's Role in California's Water Supply

The Delta is the terminus for California's largest watershed, which encompasses the western slopes of the Sierra Nevada, the eastern slopes of the coastal range, and the valleys that lie between these ranges. Water in the Delta watershed starts as precipitation in the Sacramento River and San Joaquin River watersheds and, unless diverted or otherwise used, flushes San Francisco Bay and flows out to the ocean under the Golden Gate Bridge. Once again, this estuarine delta where California's two largest rivers meet is at the geographic and political center of water in California.

The CVP and the SWP rely on the Delta's artificial network of channels to convey water stored in upstream reservoirs to regions south of the Delta including the Bay Area, San Joaquin Valley, Tulare Lake Basin, Central Coast, and Southern California. (See sidebar, Reliance on the Delta Varies by Region, and Figure 3-3.)

Because of the Delta's central location, the water demands of many Californians are connected in some way to the Delta. Water diverted from the Delta watershed provides some portion of water supply for more than 27 million of the state's residents and approximately 3 million irrigated acres of farmland (DWR 2007a, DWR 2009, DWR 2011c, Reclamation 2011b). This water plays a critical role in helping to sustain a major portion of the state's $1.9 trillion economy.

This section provides an overview of water use and water infrastructure in the Delta watershed, followed by a description of water project operations in the Delta and the challenges and conflicts associated with these. The section concludes with a discussion of the importance of improving the flexibility of project operations, through improved conveyance, storage, and water management, in achieving the coequal goals.

Use of Water from the Delta Watershed

About half the state's runoff flows through the Delta watershed. Since the 1849 Gold Rush, communities throughout California have planned and constructed facilities to tap into this water to support economic development.

Many diversions in the Delta watershed occur in the upper watershed. On average, approximately 31 percent of the flow from the Delta watershed is diverted before it ever reaches the Delta (DWR 2011c). See Figure 4-5 in Chapter 4. These diversions are done through an extensive network of locally constructed dams, canals, and diversion structures that have been built over the past 160 years on nearly every stream and drainage within the Delta watershed (California Natural Resources Agency 2010). Some of the water diverted from Delta tributaries is returned to the tributaries through wastewater effluent and agricultural return flows, albeit at a degraded quality.

Water from these diversions sustains the economies of the residents, businesses, and growers who live in the areas where the water comes from—the "area of origin"—as well as the economies in the export areas. Some of these historical diversions occur through two large aqueduct and reservoir systems that were constructed early in the twentieth century to serve the growing water demands of San Francisco and East Bay Area communities. These facilities divert water before it reaches the Delta and convey it directly to reservoirs, treatment facilities, or customers in the Bay Area region. The Hetch Hetchy reservoir system on the Tuolumne River, and the Pardee and Camanche reservoirs system on the Mokelumne River account on average for approximately 0.5 MAF, or about 1.6 percent of the flow from the Delta watershed, of annual water deliveries from the Delta's upper watershed (DWR 2009).

RELIANCE ON THE DELTA VARIES BY REGION

Water exported from the Delta supplies about 8 percent of the state's total water use, and local and regional water supplies provide over 84 percent on average. However, reliance on water from the Delta watershed varies throughout California from region to region, supplier to supplier, and user to user.

For example, in the Sacramento and San Joaquin river watersheds, including water uses on the valley floor, foothills, mountain communities, and the Delta, the vast majority of the water supply comes from local sources: the rivers and reservoirs that flow into the Delta or from local groundwater resources that are replenished from runoff within the Delta watershed. Most of this water is used for irrigated agriculture, although increasing amounts are being shifted to drinking water and other municipal uses by the cities and towns that are growing in these regions. High-growth areas surrounding the Delta, including Fairfield, Sacramento, Stockton, and Tracy, are increasing urban water use and decreasing agricultural water use as the communities are developed.

Other regions, including the Tulare Lake region of the Central Valley, the San Francisco Bay Area, the South Coast, and the Central Coast, receive some portion of their water supply from diversions from the Delta's eastern tributaries or from water that is pumped from the Delta to supplement their limited local surface water and groundwater supplies. These exports vary by region and, for specific water users, the significance of these exports varies dramatically. For example:

- **Tulare Lake:** This region relies upon exports delivered through the Central Valley Project (CVP) and State Water Project (SWP) for 27 percent of its regional water supply, and most of this water use is for irrigated agriculture (on average 96 percent of CVP water deliveries and 89 percent of SWP deliveries). Kern County Water Agency, a water wholesaler, has the largest SWP import contract in the Tulare Lake Basin at nearly 1 million acre-feet (MAF) (DWR 2009).
- **San Francisco Bay Area:** This region's predominant water supply is from local sources (57 percent from surface and groundwater alone). However, diversions from the Delta's tributary streams provide up to 27 percent of this region's water, and CVP and SWP exports account for another 16 percent (DWR 2009). The reliance of the region's individual water suppliers on water from the Delta varies dramatically; the Marin Municipal Water District uses none (MMWD 2010), and the Zone 7 Water Agency in Alameda County receives as much as 82 percent of its water from SWP exports (Zone 7 2010).
- **Southern California:** This region is home to 50 percent of the state's population (with most in densely urbanized areas), and 80 percent of its water use is for drinking water, municipal, and industrial uses. SWP exports from the Delta account for roughly 25 percent of the region's water supplies, and local sources (groundwater, surface water, and increasingly recycled water) comprise another 50 percent, and imported water from the Colorado River about 25 percent (DWR 2009). Within the Metropolitan Water District of Southern California, the largest wholesaler in Southern California, the dependence of its member agencies on SWP imports can vary dramatically. Some agencies have few alternative water sources, while others have sufficient local supplies and are now planning to reduce their future reliance on imported water or to roll off the system completely (WBMWD 2010, City of Santa Monica 2012).

With increasing uncertainty over the reliability of Delta water exports, many communities have developed plans and projects to increase and diversify local water supplies and to increase water efficiency. Even with improvements in Delta operations that provide more reliable Delta water exports, regions will need to implement additional local and regional water management strategies to reliably meet their future water demands.

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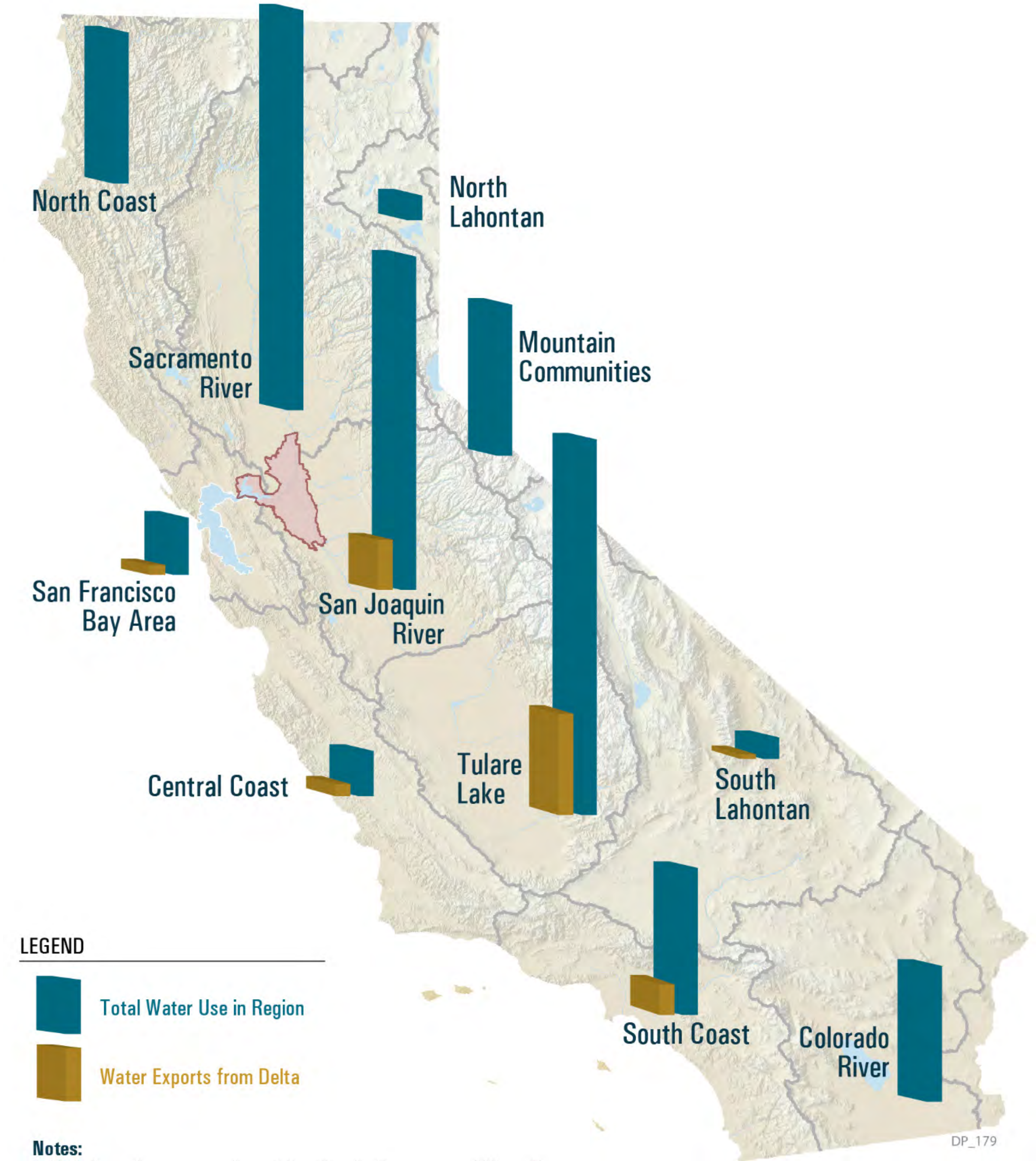
Local Water Sources Meet Most of California's Water Needs



Notes:
1. Hydrological regions are those defined by the Department of Water Resources
2. Delta water exports include contract amounts to maintain wetlands

Sources: DWR 2009, Reclamation 2011b, DWR 2011c

Figure 3-3 The vast majority of California's water comes from local sources. Exports from the Delta comprise 8 percent of California's water use. Yet, the Delta supply is important to many regions south of the Delta.

Within the Delta, growers and residents historically have relied on water from the Delta. In-Delta water use has remained relatively constant over the past 100 years (DWR 2007a) and averages about 4 percent (0.9 MAF) of inflows into the Delta. Most of this water is used for agricultural irrigation, and small and large communities throughout the Delta.

The CVP and SWP export systems became operational in the late 1940s after much of the local Delta development had occurred. Exports from the Delta now range from approximately 3 MAF in dry years to around 6.5 MAF in wet years (DWR 2009, Reclamation 2011b, Reclamation 2011c). In total, the SWP and CVP facilities export on average approximately 5.1 MAF per year from the Delta. These water diversions account for 24 percent of the inflows into the Delta (see Figures 3-4a and 3-4b).

Joint Federal and State Delta Operations

The federal CVP and California SWP were born out of long-range planning documents developed from the 1870s through the 1920s, including the 1919 Marshall Plan completed by U.S. Geological Survey and the 1930 Division of Water Resources Bulletin No. 25, "Report to the Legislature of 1931 on State Water Plan." These planning investigations developed and evaluated alternatives to provide:

- Fresh water to industries in Contra Costa and Alameda counties along Suisun and San Pablo bays
- Irrigation water to portions of the San Joaquin Valley that have substantial and increasing groundwater overdraft conditions, especially in the Tulare Lake region
- Supplemental water for Southern California urban development totaling 2 million acres in San Diego, Orange, and Ventura counties and the San Gabriel and San Bernardino valleys with water from Owens Valley, Mono Basin, and Colorado River

The California Legislature approved this plan in 1941 as the first State Water Plan (now the current California Water Plan), which included a description of facilities that would eventually be constructed as part of the CVP and SWP. Although design and construction of storage and conveyance facilities was done separately for CVP and SWP, both are operated in a coordinated manner for Delta operations.

Central Valley Project

Congress appropriated $20 million in Emergency Relief Appropriation Funds and authorized construction of the CVP by the U.S. Army Corps of Engineers (USACE) as part of the Rivers and Harbors Act of 1935. When the Rivers and Harbors Act was reauthorized in 1937, the construction and operation of the CVP was instead assigned to the Bureau of Reclamation (Reclamation).

Construction of the CVP by the federal government began in 1937. The first water was sold from the CVP to the City of Antioch from the initial reaches of the Contra Costa Canal in 1940, to support shoreline industries.

By the late 1940s, it had become apparent that California's rapid urban, agricultural, and industrial growth would quickly increase demands for water and power to levels that exceeded the initial CVP system capacity. In response, Congress authorized additional federal reservoirs and conveyance facilities over the next few decades, including Folsom Dam along the American River, Tehama-Colusa Canal along the west side of the Sacramento Valley, Trinity River Dam to provide additional water from the Trinity River into the Sacramento River for CVP operations, and New Melones Dam on the Stanislaus River. In 1960, the San Luis Unit, in the western San Joaquin Valley, was authorized by Congress to be constructed under a contract between the federal government and the State.

Where Delta Water Comes From and Goes

Data presented as a long-term average. Information based on DWR CALSIM II modeling, which includes projected conditions to protect fisheries.

Delta-Suisun in-Delta use includes water to the Contra Costa Canal and to the Mokelumne and Hetch Hetchy aqueducts.

Figure 3-4a

Over the past century, the combination of regional diversions from within the Delta watershed and water diverted directly from the Delta has transformed the Bay-Delta ecosystem, reducing historical outflows by an average of 50 percent.

Sources: LAO 2008, Reclamation 2011b, DWR 2011c

Delta Water Flows in Wet and Dry Years

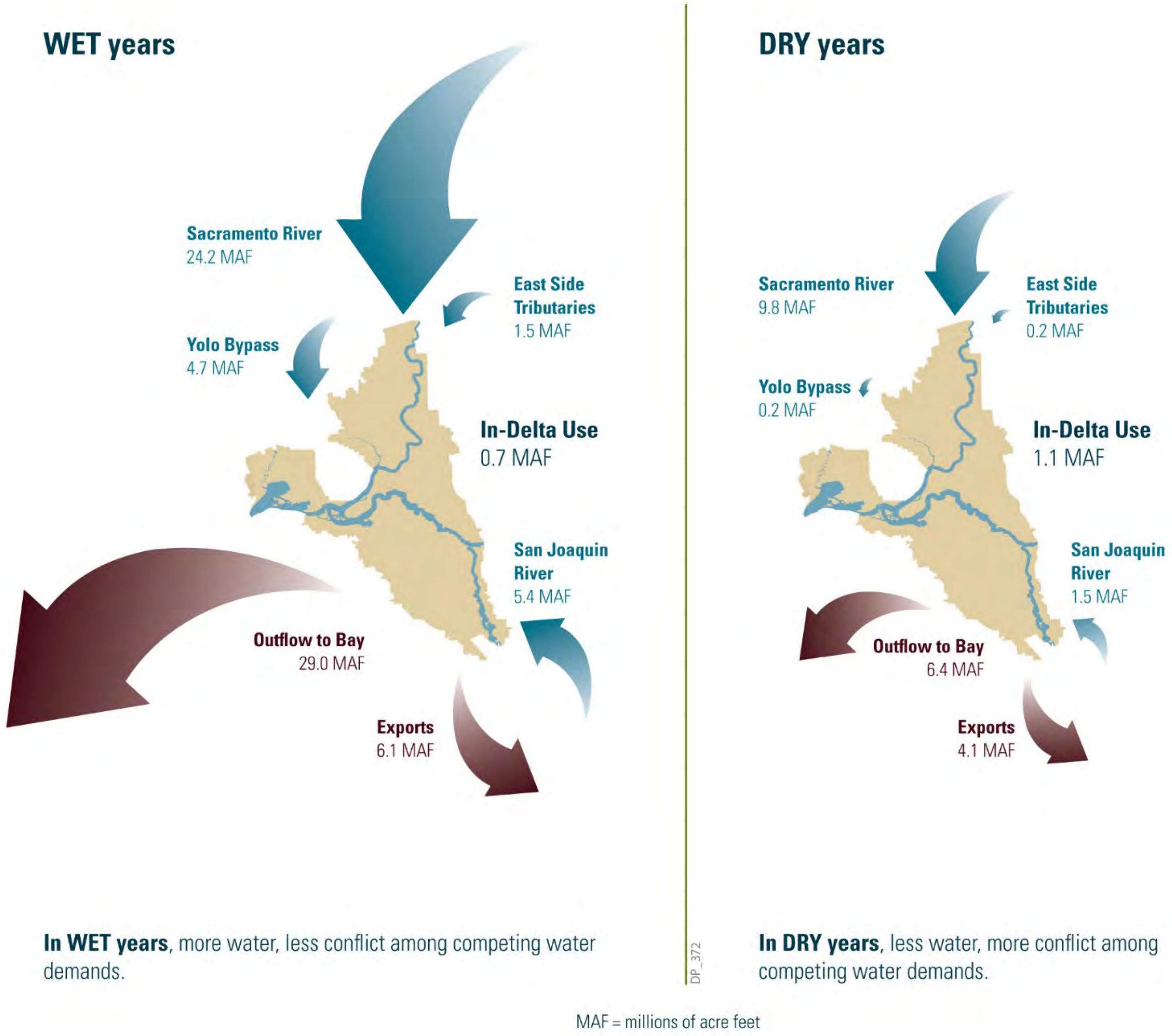


Figure 3-4b *Sources: LAO 2008, Reclamation 2011b, DWR 2011c*

The CVP is the largest surface water storage and delivery system in California, with a geographic scope covering 35 of the state's 58 counties. The project includes 20 reservoirs with a combined storage capacity of approximately 11 MAF, 8 power plants and 2 pumping-generating plants, 2 pumping plants, and approximately 500 miles of major canals and aqueducts. The CVP provides water through water service contracts and water rights agreements for a total of about 9.6 MAF per year (including water service contractors that use water from the Stanislaus River and San Joaquin River).

State Water Project

In 1947, the State began an investigation to consider the next phases of the State Water Plan to meet the state's anticipated supplemental water demands through development of the SWP and to control salinity intrusion in the Delta. In 1953, the State adopted the Abshire-Kelly Salinity Control Barrier Act to evaluate placement of a saltwater barrier near Suisun Bay to protect Delta water users and allow transfer of fresh water from the Sacramento Valley to the San Joaquin Valley. This plan was not implemented primarily due to costs and technical considerations, but alternatives continue to be evaluated today.

In 1957, Bulletin No. 3 was published, which described the need for SWP facilities to convey water from the Sacramento Valley to water-short areas of California. The report identified an urgency to expand statewide water facilities because of projected population growth and to support a balanced economy; major industrial growth; 6,875,000 acres of irrigated agriculture, or approximately 25 percent of all agricultural acreage in the United States; and flood control in Northern California. The study identified that there was a "seasonal deficiency" of 2,675,000 acre-feet of water in 1950 that had been met with groundwater pumping primarily from overdrafted aquifers. In 1960, California voters authorized the Burns-Porter Act to construct the initial projects of the SWP, including Oroville Dam and Lake Oroville on the Feather River, San Luis Dam and Reservoir to be jointly constructed and operated with Reclamation, the North and South Bay aqueducts, and the 444-mile California Aqueduct. Notably, DWR continues to project a 1- to 2-MAF deficit in average annual groundwater pumping from overdrafted aquifers (DWR 2009). A more detailed discussion of groundwater is provided later in this chapter.

Delta Operations

Prior to the 1960s, the CVP and SWP operated in the Delta unrestrained by environmental regulations. However, beginning in the 1970s, with the passage of environmental laws, including the federal Clean Water Act, Endangered Species Act, Central Valley Project Improvement Act, Porter-Cologne Water Quality Control Act, California Endangered Species Act, Wild and Scenic legislation, and many others, protection of the ecosystem became an explicit legal obligation for the SWP and CVP in addition to delivery of fresh water for agricultural and urban use.

In the modern context, CVP and SWP facilities operate according to a complex web of permits, licenses, and, in some cases, court orders that impose explicit conditions on how, when, and how much water can be exported from the Delta. Some of the entities that regulate water project operations in and upstream of the Delta include:

- The SWRCB and regional boards require the SWP and CVP to meet specific water quality criteria that result in operational standards within the Delta and the Delta watershed. The SWRCB also sets instream flow standards.
- USACE sets operational "rule curves" for reservoirs that provide flood protection upstream of the Delta. The Central Valley Flood Protection Board regulates encroachments on designated floodplains and floodways. (See Chapter 7.)
- The presence of threatened and endangered species in California's waterways and landscapes requires the California Department of Fish and Wildlife (DFW), U.S. Fish and Wildlife Service, and National Marine Fisheries Service to regulate water project operations in the Delta. Federal biological opinions that govern agency regulatory activities have been the subject of extensive recent litigation by water agencies and other interested parties.

To comply with these regulations and to optimize system efficiencies, DWR (for the SWP) and Reclamation (for the CVP) jointly coordinate their pumping operations in the Delta under the 1986 Coordinated Operating Agreement (COA). One of the benefits of the COA is that it resulted in improved reliability of deliveries for the SWP (DWR 2008). They also jointly manage portions of the water delivery facilities in the Central Valley. There are times when the CVP may use SWP export capacity or that the SWP may need to use CVP export capacity. This close coordination has resulted in flexible operation of the Delta facilities to improve reliability of Delta water deliveries as well as to reduce system vulnerability to disruption.

Additional operational changes are on the horizon for the CVP and SWP. The SWRCB has initiated a phased process to review and amend—or to adopt new—water quality and flow objectives for the Delta by 2014. Phase 1 of that review is focused on southern Delta water quality and San Joaquin River flows. Phase 2 is focused on other changes that may be needed to the remainder of the Bay-Delta Water Quality Plan to protect fish and wildlife beneficial uses. See Chapter 4 for more information on flow in the Delta and the relationship to ecosystem health, and Chapter 6 for more information on the Council's recommendations on the SWRCB process to update the Bay-Delta Water Quality Plan. Furthermore, conveyance alternatives under consideration by the Bay Delta Conservation Plan (BDCP) could mean large-scale changes to Delta infrastructure and operations.

Challenges and Conflicts in the Delta

Over time, the Delta has been transformed, mostly by human hands, to serve many purposes. As mentioned, the SWP and CVP were originally engineered to reliably deliver water to water service contractors and water rights holders without commensurate consideration for impacts on native species. The Delta is the only saltwater estuary in the world that is used as a conveyance system to deliver fresh water for export. This creates substantial water supply and ecosystem conflicts.

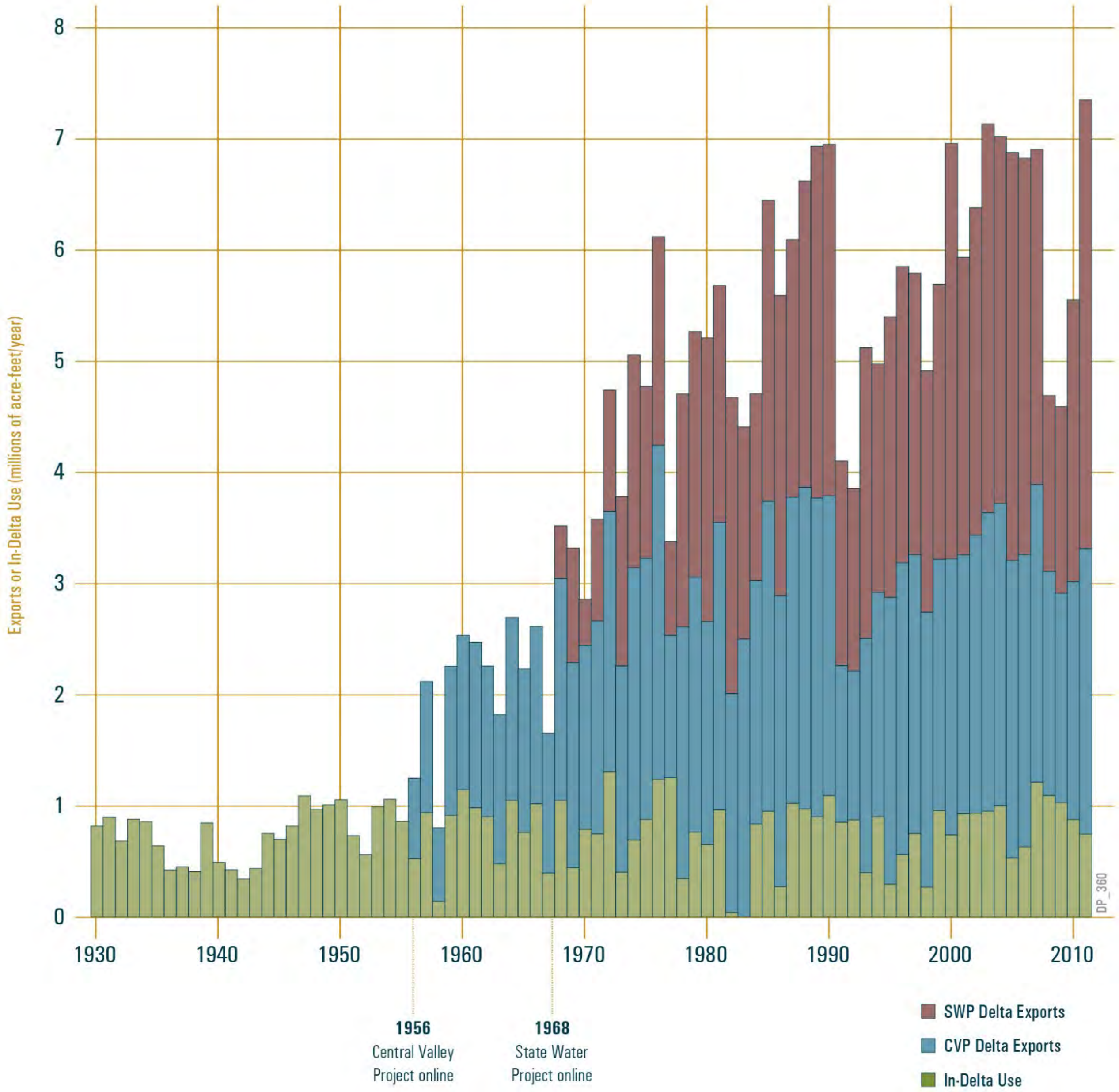
Legal changes in recent decades, combined with growing societal awareness and scientific understanding of water project operations on ecosystem health, had major implications for water operations in the Delta. The collision of changing societal values, growing demands for water deliveries from the Delta, and declining health of the Delta ecosystem have resulted in numerous complex and often bitter legal challenges that have increasingly shifted critical Delta water management decisions to the courts.

CVP and SWP Water Delivery Challenges

Overall, exports from the Delta have been rising over the past 4 decades (see Figure 3-5). Historically, the SWP and CVP have pumped more water from the Delta during dry years than wet years; but over time, exports have increased in all water year types, except in critically dry years. The SWP and CVP have each reached record exports in the past 10 years. In part, this is because recent increases in surface and groundwater storage south of the Delta have enabled more water to be taken during wet years. Increased south-of-Delta storage has also led to more agricultural-to-urban water transfers, which help improve the flexibility of operations in the Delta.

Yet, many factors threaten the ability of State and federal water managers to continue pumping water through the two projects at current export levels. Subsidence of the agricultural lands on the Delta islands, rising sea level, and earthquakes threaten the physical integrity of the Delta ecosystem and the levees that protect the export water quality. The location of the two pumping stations (one each for the CVP and SWP) in the south Delta is a problem for fisheries. Described previously, most of the water enters the Delta from the north through the Sacramento River. Pumping stations for the CVP and SWP are located in the south Delta and, when operating, frequently cause a net "flow reversal" in the central and south Delta channels. (See Chapter 4 for more details.) This reverse flow affects fish movement, including migration through the Delta, and often results in species that are free-floating or have weak swimming capability being drawn into the pumping facilities where they can be entrained (Grimaldo et al. 2009). Water quality is an issue too. A portion of the water flowing into the Delta is specifically allocated to Delta outflow to help repel salinity intrusion from the San Francisco Bay and to maintain low-salinity water near the western edge of the Delta. This means that water that might otherwise be used for exports must be released from upstream reservoirs to help control salinity (NRC 2012).

Historical Exports and In-Delta Use



1956
Central Valley
Project online

1968
State Water
Project online

Figure 3-5 Overall exports from the Delta have been rising over the past 4 decades, while in-Delta uses have remained fairly constant. Exports by the CVP and SWP have reached record levels in the past 10 years.

Conflicts over water use are further complicated by original SWP and CVP contracts that assumed greater water export quantities than consistently can be delivered. Since 1990, the CVP has fulfilled 100 percent of its contract water allocations only three times, and the SWP has delivered 100 percent of its contract amounts only twice (Reclamation 2011c, DWR 2010b). The CVP's ability to meet maximum contracted amounts, particularly during dry years, has diminished since the addition of new municipal and industrial contractors who have priority over agricultural water deliveries.[10] Also, the 1992 passage of the Central Valley Project Improvement Act dedicated up to 800,000 acre-feet of CVP exports for wildlife refuges and environmental needs (Public Law 102-575, section 3406(b)(2)). The original SWP contract amounts were based on assumptions that additional major new dams and conveyance facilities would be constructed at a later date, which did not occur. As a result, even though the SWP had contracted to supply 4.2 MAF, average SWP exports between 1996 and 2006 were just 2.9 MAF (DWR 2008).

The reality is that the State and federal systems have never been able to reliably deliver the full contract amounts. Now, additional court-ordered and regulatory restrictions on State and federal pumping of export water, in combination with the 2007 through 2009 drought, further reduced the reliability of Delta water exports to SWP and CVP contractors. According to DWR, SWP deliveries are now expected to average 60 percent of maximum contract amounts in future years, down from 66 to 69 percent estimated in 2005 (DWR 2010b).

The process for allocating water shortages within the State and federal projects also impacts the extent to which various contractors experience different levels of Delta water supply reliability. Within the SWP, shortages are uniformly distributed across all water contractors. Within the CVP, municipal and industrial water users have a higher priority than agricultural water users. As a result, in dry years, CVP water rights contractors, such as the Sacramento River Settlement Contractors, may receive 100 percent of their water allocations while non-water rights contractors, including Westlands Water District, may receive as little as 10 percent.

North-to-south water transfers across the Delta can be an important tool for improving water supply reliability. However, transfers require the use of SWP or CVP facilities and, as such, are subject to the regulatory constraints on Delta exports. Because Delta pumping windows of opportunity are shorter and generally filled by contract deliveries, excess capacity for water transfers is increasingly hard to come by.

Although lesser known, an increasing challenge to Delta export reliability relates to the operations and maintenance of the large, complex facilities that make up the SWP. The SWP has experienced a significant and growing decline in operational reliability that has directly impacted DWR's ability to store and move water, produce electricity, and export water from the Delta when the appropriate hydrological conditions present themselves (DWR 2010b). These challenges include maintaining SWP delivery capabilities under continued manpower resource limitations, aging infrastructure, and constraints in providing competitive employee compensation despite adequate SWP funding. Further resource challenges are attributed to complex and cumbersome State contracting processes and State hiring freezes.

Improving Delta Water Supply Reliability through Investments in System Flexibility

Because California's annual precipitation is remarkably variable, the past expectation that each year—wet or dry—should yield the same quantity of water exported from the Delta watershed is unrealistic and can be an obstacle to necessary improvements in water supply reliability.

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[10] Additional municipal and industrial water contracts were implemented in the late 1980s for the CVP San Felipe Unit and in the last 10 years for the CVP American River Division.

The greatest conflicts between the water needs of people and fish within the Delta occur during dry years. That is when the least amount of water is flowing into the Delta and, historically, when exports have been a much larger percentage of Delta inflows than in wet years (see Figure 3-6). On average, exports have diverted about 17 percent of Delta inflows in wet years and about 36 percent during dry years (DWR 2011c). In past years, exports have exceeded 60 percent of Delta inflows in some dry months, but recent regulatory decisions now constrain such operations.

The recovery of the Delta ecosystem and listed species will help reduce regulatory restrictions on Delta exports and increase the long-term stability and predictability of rules governing Delta pumping.

More natural flow patterns in the Delta can be compatible with improving the reliability of water deliveries from the Delta. More water can be taken in wet years when more water is available, less water will be taken in dry years when it is needed for in-Delta water quality and environmental protections, and operations can be improved to increase seasonal flexibility to avoid impacts on Delta species and habitat. Many local water management actions that help reduce reliance on the Delta and improve regional self-reliance are also essential to improving overall flexibility of Delta operations and improving reliability of water supplies during periods when pumping is constrained.

Upstream, downstream, and in-Delta improvements can all add to export system flexibility, producing both water supply and ecosystem benefits. Storage capacity, however, is a current limitation to this scenario, and will worsen under anticipated climate change conditions. Were sufficient storage available, flows that exceed water needed to meet environmental and other requirements could be captured and stored. This stored water could then be released later in the year or carried over into subsequent years.

Fish predation and mortality at the export pumps could be reduced if the diversion points of the State and federal water projects in the Delta were moved or modified. Risks to a reliable source of fresh water conveyed through the Delta could be reduced through conveyance alternatives that could provide multiple diversion locations in the Delta (as those being analyzed in the BDCP process) and through strategic levee investments.

It is important to note that storage can increase the benefits of conveyance improvements, and conveyance improvements may be limited without the benefit of added storage. Improved operational flexibility, consistent with ecosystem restoration, can result in more reliable water supplies for all beneficial uses from year to year and, when managed for multiple benefits, can also ensure adequate flows to meet public trust needs, including the protection of the Delta ecosystem.

The Role of Storage in Increased Flexibility

Statewide water storage capacity, both above and below ground, is currently inadequate, especially south of the Delta, to facilitate export of water at times of surplus when the impacts on the Delta's ecosystem are reduced and the only impediment is lack of available storage capacity (DWR 2009). For example, in 2010, the SWP and CVP pump operations were slowed even though water was available to be pumped at a time when it would not have conflicted with endangered species or other water quality requirements. The SWP and CVP could not convey the surplus water through the Delta at that time because storage capacity south of the Delta was full.

Historical Delta Inflow and Delta Exports

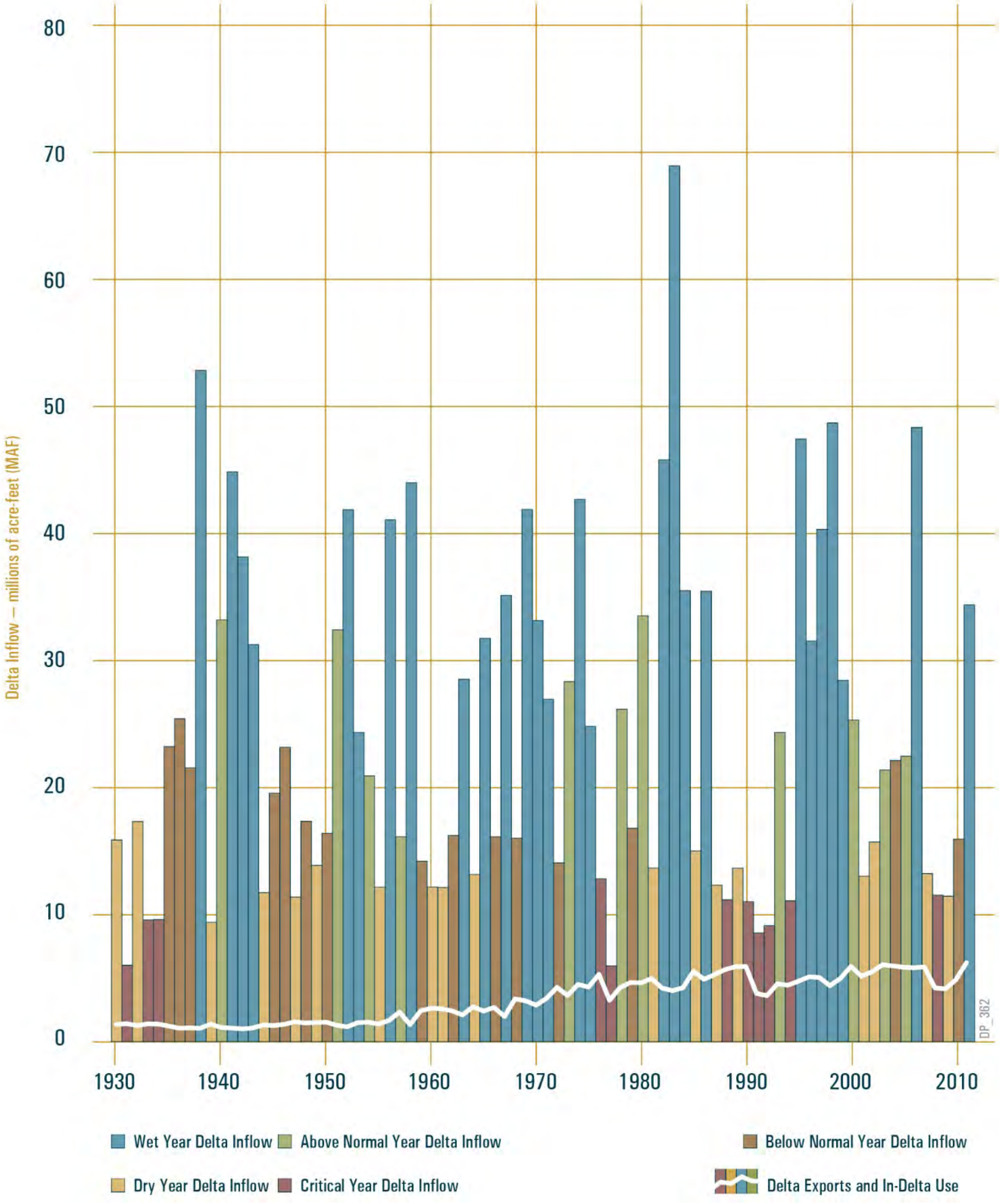

Figure 3-6

In many years, water flowing into the Delta greatly exceeds the amount of water that is exported from or used in the Delta. However, in dry years, total exports and in-Delta use have averaged as much as 36 percent of inflows.

Source: DWR 2012a

Applying Adaptive Management To Water Management Decisions

An adaptive management approach for water management decisions should be taken to plan for and assess the water supply outcomes of conveyance and storage improvement actions. The following is a hypothetical example of how the Council's three-phase and nine-step adaptive management framework (see Appendix C) could be applied to a water management decision.

		Adaptive Management Step	Hypothetical Water Supply Reliability Improvement Project
Plan	1	Define/redefine the problem	Current storage and conveyance configuration is not adequate for providing a more reliable water supply to south-of-Delta users under modern operating rules.
	2	Establish goals and objectives	**Goal:** Improve water supply reliability for south-of-Delta water users. **Objective:** Optimize storage for south-of-Delta water users in wet years so that interruptions in deliveries are reduced and the amount of water delivered during wet years can be increased consistent with environmental regulations in the Delta.
	3	Model linkages between objectives and proposed action(s)	There are inadequate options for south-of Delta water users to optimize storage in wet years, leading to vulnerability to interruptions and reduced capacity to divert water when it is available. The San Luis Reservoir is the only CVP water source for San Luis Unit, Cross-Valley Contractors, and San Felipe Division (SFD) water users. SFD serves water to Santa Clara and San Benito counties. As the San Luis Reservoir is drawn down during the summer and into the late fall (when predictable water supplies are needed most), a dense layer of algae develops near the surface. As the water level lowers, this algae gets captured by SFD intakes. The algae degrade water quality and make water more difficult to treat. As a result, SFD deliveries can be interrupted when the reservoir falls below 300,000 acre-feet. It is hypothesized that improving the San Luis Reservoir low-point intake would increase the predictability of water deliveries and make more water available to south-of-Delta water users during dry years. Alternatives to improving the low-point intake could include expanding the Pacheco Reservoir to provide storage for SFD water users. As a result of taking one or a combination of these actions, progress would be made toward improving water supply reliability for south-of-Delta water users by (1) reducing potential for interruptions, (2) diverting more water during wet years, and (3) making this water available during dry years when water from the Delta may not be available.
	4	Select action(s) (research, pilot, or full-scale) and develop performance measures	**Selected Action:** Conduct feasibility analyses and modeling to determine which option would enable the highest increase in the reliability of water conveyance for south-of-Delta users in compliance with environmental requirements. **Performance Measures:** ▪ Administrative – Complete feasibility analyses and modeling. ▪ Output – Select and implement an improvement project (e.g., improve the low-point intake at San Luis Reservoir only). ▪ Outcome – Progress toward improving water supply reliability by (1) reducing potential for interruptions, (2) diverting more water during wet years, and (3) making this water available during dry years when water from the Delta may not be available.
Do	5	Design and implement action(s)	Design and implement the feasibility analyses and modeling.
	6	Design and implement monitoring plan	Design and implement the monitoring plan, including baseline monitoring, and measurement of (1) reduced interruptions of SFD deliveries when the reservoir falls below 300,000 acre-feet, (2) the amount of increased delivery of water during wet years, and (3) the amount of increased water deliveries from the reservoir during dry years to offset reduced Delta diversions.
Evaluate and Respond	7	Analyze, synthesize, and evaluate	Analyze, synthesize, and evaluate the feasibility analyses and model outputs, and make recommendations for selecting a project or adjusting the conceptual model.
	8	Communicate current understanding	Provide project manager(s) and decision makers with synthesized information learned. For example, present information on the extent to which interruptions would be reduced, the value of the reduced interruptions, and the benefits of a specific operation scheme as part of a cost-benefit analysis.
	9	Adapt	The DWR, Reclamation, and SFD contractors decide on a pilot- or full-scale improvement project.

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In the past decade, the State has spent tens of millions of dollars on integrated studies to evaluate how large surface storage and conveyance may be improved. DWR is now completing surface storage investigations that were initiated under CALFED more than 10 years ago (DWR 2010a). The three proposed new major surface storage reservoirs that are being evaluated are the North-of-the-Delta Offstream Storage (Sites Reservoir), Los Vaqueros Reservoir Expansion, and Upper San Joaquin River Basin Storage investigation (Temperance Flat Reservoir). DWR expects to make its decision on recommended projects by 2014.

In the meantime, smaller facility improvements, particularly for storage, are being implemented. Since 1995, more than 1.2 MAF of additional surface storage has been constructed at the regional level, including the Diamond Valley, Seven Oaks, and Olivenhain reservoirs in Southern California, and the Los Vaqueros Reservoir in Contra Costa County.[11] The sidebar, Applying Adaptive Management to Water Management Decisions, provides a hypothetical example of an approach to providing more reliable water supplies.

A legacy of both overdraft and water quality contamination has compromised groundwater storage in many regions of the state; however, important improvements are being made through expanded regional groundwater storage north and south of the Delta. Notably, an assessment of groundwater storage in 2000 identified more than 21 MAF of potential groundwater storage in Southern California and the southern portion of the San Joaquin groundwater basin (AGWA 2000). A more detailed discussion of groundwater management in California is included later in this chapter.

Significant opportunities are available to improve the operation of existing storage and conveyance facilities, build small-scale storage projects, or enhance opportunities for groundwater conjunctive management and water transfers in the next 5 to 10 years that are consistent with the coequal goals. DWR is leading a System Reoperation Task Force with Reclamation; USACE; and other State, federal, and local agencies to study and assess opportunities for reoperating existing reservoir and conveyance facilities to improve flood protection and capture of available water runoff, particularly in the context of climate change. Reservoir reoperation is also addressed in Chapter 7.

Many local storage and conjunctive management projects were identified through competitive State and federal grant funding application processes in the past decade. Most of these projects could not be funded because of limited funding and restrictions in some of the grant provisions. Later in this chapter, the New Water for California section provides further detail on the range of options and describes necessary steps that regions should take to improve regional self-reliance and reduce reliance on the Delta.

The Role of Conveyance in Increased Flexibility

Conveyance improvements can enhance the operational flexibility of the Delta system to divert and move water at times and from locations that are less harmful to fisheries, or to reliably transport environmental water supplies to specific locations at times when it can benefit fish and water quality (California Natural Resources Agency 2010). Existing configurations of Delta water conveyance and associated conveyance facilities do not provide adequate long-term reliability to meet current and projected water demands for SWP and CVP water exports from the Delta watershed (DWR 2009).

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[11] Contra Costa Water District will complete a 160,000-acre-foot expansion of Los Vaqueros Reservoir in 2012. The feasibility of an additional 275,000-acre-foot expansion is still under consideration by State and federal agencies.

Conveyance improvements and associated ecosystem restoration actions are being evaluated as part of the multiagency BDCP effort. (See sidebar, Bay Delta Conservation Plan and Water Supply Reliability.) Once decisions are made regarding whether to build and, if so, in what manner to build conveyance improvements, construction of these facilities will likely take at least a decade or more and will not provide near-term reliability improvements. This means that Delta operations and deliveries of export supplies will continue to be constrained by existing infrastructure for at least the next 15 years.

During this time, steps must be taken to implement local water management programs and projects, described later in this chapter. Additionally, the State needs to address the continuing vulnerability of the Delta levee system and make improvements to protect the existing in-Delta conveyance system from catastrophic failure. (See Chapter 7 for a discussion of the benefits and vulnerabilities of Delta levees.) In particular, immediate improvements to the Delta levee system are critical because of the current instability and interdependence of the levees—the failure of one can affect the entire system (NRC 2012).

BAY DELTA CONSERVATION PLAN AND WATER SUPPLY RELIABILITY

The BDCP is a Habitat Conservation Plan (HCP) and Natural Community Conservation Plan (NCCP) that "proposes major physical changes to the Delta, including new diversion and conveyance facilities and their operational criteria, extensive new aquatic habitat, and other measures to help reverse the Delta's ecological decline and secure water supplies from the Delta for human use" (BDCP 2012c).

The BDCP is planned to be implemented over a 50-year timeframe using an adaptive management and monitoring program to adapt as conditions change and new information emerges. The parties seeking one of several permits pursuant to the BDCP include DWR, Reclamation, Metropolitan Water District of Southern California, Kern County Water Agency, Santa Clara Valley Water District, Zone 7 Water Agency, Westlands Water District, and the State and Federal Water Contractors Agency (BDCP 2012a). The goal of these parties, with the exception of Reclamation, is to formulate a plan that could ultimately be approved by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service as an HCP under the provisions of Endangered Species Act section 10(a)(1)(B) and as an NCCP by DFW under Fish and Game Code section 2800 et seq. and/or the California Endangered Species Act section 2050 et seq. Reclamation intends to use information developed as part of the BDCP process to help inform its Endangered Species Act Section 7 consultation on the coordinated long-term operation of the CVP and SWP with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. If the BDCP is successfully completed, and DFW determines that the BDCP meets the requirements in Water Code section 85320, it must be incorporated into the Delta Plan. That determination by DFW may be appealed to the Council (Water Code section 85320 (e)).

The BDCP is being developed to contribute to improving water supply reliability by modifying Delta conveyance facilities to create a more natural flow pattern in the Delta and allow for water exports when hydrologic conditions result in the availability of sufficient water, consistent with the requirements of State and federal law and the terms and conditions of SWP and CVP water delivery contracts, and other existing applicable agreements.

The BDCP process is considering a range of options for conveying water through or around the Delta:

- **Through-Delta Conveyance:** Continue to divert water in the southern Delta at existing or modified intakes/diversions for SWP and CVP operations.
- **Isolated Conveyance:** Divert water from the Sacramento River at new intakes/diversions and convey the water to the existing SWP and CVP pumping plants through a pipeline/tunnel.
- **Dual Conveyance:** Combine through-Delta conveyance and isolated conveyance to allow operational flexibility.

The BDCP process is ongoing. As of this publication, the public draft of the BDCP and the related environmental impact report/environmental impact statement are planned for release by late 2012, with final documents expected to be released in mid-2013 (BDCP 2012b). The Council is a Responsible Agency for California Environmental Quality Act purposes.

New Water for California

The fact that water is a scarce resource does not mean that California is "running out of water" (NRC 2012). It does mean that California will need to develop plans, and implement programs and projects that can adapt to a highly variable and uncertain water future. The primary source of new water supplies for California in the future will come from local and regional sources.

This section discusses local water supply opportunities, the importance of local and regional water management planning, and the need for improved groundwater management and water data so that the state can better match its water demands to the available supplies.

California's Wealth of Water Opportunities

California has many new and underused water resources that can be developed to improve regional self-reliance. In 2009, DWR estimated that the state could further reduce water demand and increase water supplies in the range of 5 to 10 MAF by 2030 through the use of existing strategies and technologies (see Figure 3-7).[12] If the state developed only half this water (about 5 MAF) through water efficiency and new local supplies, it would be sufficient to support the addition of almost 30 million residents, more than the population growth that is expected to occur by 2050.[13]

Nearly all these potential supplies will come from a combination of improved conservation and water use efficiency in the urban and agricultural sectors, local groundwater and surface storage, conjunctive management, recycled water, drinking water treatment, groundwater remediation, and desalination. DWR has identified 27 "resource management strategies" that water suppliers should consider when expanding their water management programs throughout the diverse regions of the state (DWR 2009). Resource managers can combine these strategies into a response package, crafting them to provide multiple water resource benefits, diversify their water portfolio, and become more regionally self-reliant.

Often, the new local and regional water supplies have the additional advantage of being available even during extreme drought conditions, making them some of the most reliable sources of water for urban and agricultural uses. In particular, recycled water and the treatment and reuse of poor-quality groundwater are two of the most resilient water supplies under conditions of drought and climate change. The treatment of poor-quality groundwater also can significantly improve drinking water supplies, especially for rural and economically disadvantaged communities that have limited alternatives to secure clean water. In 2012, the California Legislature enacted Assembly Bill (AB) 685, declaring the established State policy that "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes" (Water Code section 106.3 (a)). For more about drinking water quality, see Chapter 6.

For some local water resources, California has adopted specific targets, including:

- **Urban water conservation.** The State's goal is to achieve a reduction in statewide per capita urban water use of 20 percent, from a 2005 baseline of an estimated

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[12] The range of 5 to 10 MAF is a conservative estimate and is consistent with recent studies that assess California's potential for increased water savings and water supplies. DWR provides a cautionary note that the water supply benefits summarized in the California Water Plan are not intended to be additive, recognizing the same resource management strategies may complement or compete with one another for funding, system capacity, or other elements that are necessary for implementation. In addition, unlike the 2005 version, DWR did not include in the 2009 California Water Plan an estimate for water supply benefits from improved conveyance. Instead, DWR states that the main benefits of conveyance improvements are increased water supply reliability, water quality protection, and operational flexibility (DWR 2009).

[13] Under California law, water conservation is considered a source of supply (Water Code section 1011(a)). A 2008 report from the Los Angeles Economic Development Corporation found that "using water more efficiently reduces demand, which has the same effect as adding water to the system." For Southern California, the report concludes that "urban water conservation could have an impact equivalent to adding more than 1 MAF of water to the regional supply (about 25 percent of current annual use)" (LAEDC 2008).

198 gallons per capita daily (GPCD) to 166 GPCD (DWR 2012b). This represents a potential annual water savings of approximately 1.8 MAF per year that will be accomplished by 2020. This is consistent with DWR's 2009 estimate that 2.1 MAF can be conserved in roughly the same period through increased use of water-efficient appliances, reduced water use for landscaping, and tiered rate structures, such as increasing block rates or budget-based rate structures.

- **Recycled water.** The State's goal is to increase the use of recycled water over 2002 levels by at least 1 MAF per year by 2020, and by at least 2 MAF per year by 2030 (DWR et al. 2010). DWR's 2009 estimate indicates that as much as 2.25 MAF could be recovered, about half of the amount of wastewater that is treated and released to flow to the ocean.
- **Stormwater runoff.** The State's goal is to increase capture and reuse of stormwater by at least 500,000 acre-feet per year by 2020, and at least 1 MAF per year by 2030 (DWR et al. 2010). The 2008 Scoping Plan for California's Global Warming Solutions Act of 2006 (AB 32) finds that up to 333,000 acre-feet of stormwater could be captured on an annual average for reuse in Southern California alone (CARB 2008).

California's Wealth of New Water Supplies

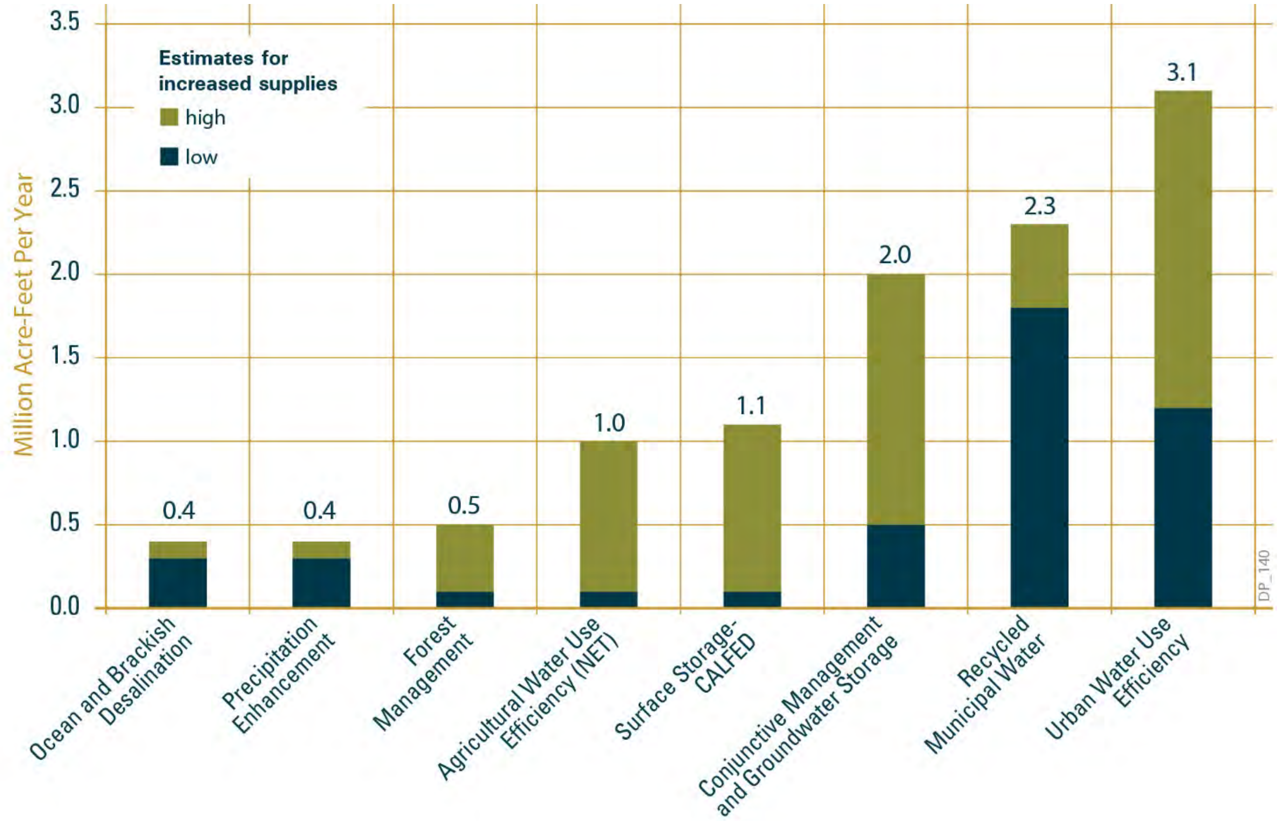

Figure 3-7 DWR estimates that California could further reduce its water demands and increase water supplies by 5 to 10 MAF per year over the next 30 years through the use of existing technologies.

Source: DWR 2009

The Importance of Local Water Management Planning

Over the past few decades, the State has built on successful local water management planning and, when possible, has provided funding for local districts to develop and implement water management plans. These plans are of benefit to all regions, not just those who rely on the Delta or Delta watershed.

These programs and projects increase the reliability of water supplies by increasing water efficiency and diversify the portfolio of water sources for urban and agricultural water suppliers that are more resilient under conditions of drought, emergency shortage, and climate change. Water developed through these activities can help reduce conflicts among urban, agricultural, and environmental uses, and can contribute to the ability of regions in California to reduce their reliance on water from the Delta watershed.[14]

The responsibility for implementing most of these water management strategies and achieving State objectives lies with over 600 local water agencies, including several privately owned and operated companies, plus wastewater districts, community service districts, and other special districts. The sheer number of local agencies engaged in water management makes it difficult to monitor and account for the significant new amounts of water supplies and increased water efficiency that is being implemented. Later in this chapter, the Informed Decision Making Requires Information section details this challenge and associated water management implications.

Since the mid-1980s, California has enacted progressively more stringent water conservation, efficiency, and water planning requirements for urban and agricultural water suppliers (see Appendix H). Beginning in 1983, wholesale and retail municipal water suppliers (those with at least 3,000 connections or delivering at least 3,000 acre-feet per year) have been required by the Urban Water Management Planning Act to prepare 20-year urban water management plans to guide investments in future water reliability. This law has been strengthened through several revisions to include specific water conservation goals (such as the 20 percent reduction in urban per capita water usage by 2020 adopted in 2009), compliance with demand management measures including adoption of rate structures that promote water conservation (AB 1420 in 2007), landscape conservation requirements (AB 1881 in 2006), and required installation of water meters (AB 2572 in 2004).

Existing law requires that urban water suppliers include a water supply reliability element and water shortage provisions in their urban water management plans, recognizing that suppliers need to prepare for extended droughts, the effects of climate change, and potential catastrophic interruption of deliveries caused by earthquakes or other events. Water suppliers must evaluate whether their water sources may be available at a consistent level of use and describe their plans for supplementing or replacing these sources, to the extent practicable with alternatives or water demand management measures (Water Code section 10631(c)(2)). Water suppliers must also describe the tools and options that will be used to maximize resources and minimize the need to

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[14] As used in the Delta Plan, "regions" refer to the 10 hydrologic areas identified by DWR that correspond to the state's major water drainage basins, and included the two regional overlays for the Mountain Counties area and the Delta. The use of these regions as planning boundaries allows consistent tracking of their natural water runoff and accounting of surface and groundwater supplies.

import water from other regions (Water Code section 10620(f)).

Agricultural water suppliers (those that provide water to 25,000 or more irrigated acres, or 10,000 irrigated acres and who receive State funding to implement the plan provisions) have a requirement similar to urban suppliers and must prepare agricultural water management plans. The Agricultural Water Management Planning Act was adopted in 2009 (Senate Bill X7 7 [SBX7 7]). Requirements include reporting on farm gate water deliveries, adoption of rate structures that promote water conservation, and identification and implementation of locally cost-effective and technically feasible water efficiency measures.

Since 2000, the State has also promoted voluntary integrated regional water management plans (IRWMPs), recognizing that collaboration among multiple agencies, especially within watersheds, provides opportunities for better water management decisions and coordinated infrastructure investments. Significant bond funding has been made available to support implementation of projects identified through these IRWMPs. A 2006 report on the investments made for IRWMP projects identified over 1.2 MAF of water benefits in combined water supply and demand reductions that have been achieved through the expenditure of $1 billion in State bond funds in local and regional projects (DWR 2009). An additional $1 billion or more of local dollars were leveraged because of this State investment. Applicants for IRWMP funding must now demonstrate how their plans help reduce their region's dependence on water imported from outside their region (DWR 2010c).

As climate change begins to affect California's water supplies, the U.S. Environmental Protection Agency (Region 9) and DWR are encouraging water managers to plan for these impacts and to take steps to adapt to them. IRWMPs, and the agricultural and urban water management plans provide an excellent framework for addressing water-related climate change impacts (USEPA and DWR 2011). Because each region is unique, there is no single "correct" planning approach. Key concepts include risk assessment, such as the potential for interruption of water supplies for up to 36 months due to catastrophic events impacting the Delta, including earthquakes or floods. For example, DWR identified the potential for some portion of Delta deliveries to be interrupted for up to 36 months if a catastrophic earthquake occurred (DWR 2010b). Although this would have a primary impact on water suppliers that rely on water from the Delta, it might also affect upstream water suppliers that may be called upon to release more water into the Delta during the crisis.

Another useful tool is the regional water balance. According to DWR, the purpose of a regional water balance is to provide an accounting of all water that enters and leaves a specific hydrologic region, how it is used, and how it is exchanged between regions. A regional water balance can be used to compare how water supplies and uses in a region can vary between wet and critically dry hydrologic conditions, and how each region's water balance compares with other regions and with the state's overall water balance. This is important to all water planning activities and provides a basis for evaluating unsustainable water management practices and making appropriate improvements (DWR 2009).

Implementing a Path to Success in Local Water Management

Many agricultural and urban water suppliers are taking commendable action to improve water conservation and efficiency, and to expand their local and regional water supplies. (See sidebar, Regional Success Stories.) However, others are not.

For example, despite longstanding State laws that require preparation and implementation of urban water management plans, many water suppliers still regard these plans as voluntary because the only consequence of not completing them has been ineligibility to receive State grant and loan funding

REGIONAL SUCCESS STORIES

Significant improvements in water management are being implemented throughout California, especially in regions that rely upon water from the Delta and the Delta watershed. The 2010 urban water management plan updates and voluntary IRWMP grant applications filed in 2010 provide insight into what individual water agencies and regional planning efforts are doing to improve water efficiency and develop additional local water supplies. Examples of successful strategies to reduce reliance on the Delta and improve regional self-reliance follow.

In Southern California:

- **West Basin Municipal Water District.** Increased water efficiency and diversification of the district's water supplies between 2010 and 2035 will enable West Basin Municipal Water District to reduce its potable water demand despite expected future population growth. The total volume of imported water usage is projected to decline by 40,000 acre-feet over this period, and conservation, recycled water, and ocean desalination will expand the district's water resources by over 60,000 acre-feet (RMC Water and Environment 2011).
- **City of Los Angeles.** Today the City of Los Angeles uses less water than it did 30 years ago, despite population growth of more than 1 million residents. In 2011, per capita water usage was 123 gallons daily—the lowest in Los Angeles in more than 40 years and the lowest among any United States city with a population over 1 million (LADWP 2012). Through regional watershed planning efforts, the city is bringing together local and county public works departments, planning agencies, local and regional water supplies, and citizen groups to develop integrated multibenefit projects. In 2004, the city overwhelmingly approved Proposition O, which authorized $500 million in local bonds to fund water efficiency, stormwater capture, water treatment, recycled water, flood protection, open space, recreation, and other projects.

In the central San Joaquin Valley and Tulare Lake regions:

- **Poso Creek Regional Water Management Group.** The IRWMP focuses on more effective coordination of each participating irrigation district's water assets, recognizing that competition for the three sources of water that meet the region's demands (local supplies/Kern River, CVP, and SWP) is increasing. Proposed improvements include 400 acres of spreading ponds and additional conveyance (canals, pipelines, and pumping plants) between the Friant-Kern Canal and California Aqueduct and among irrigation districts, which will enable the region to take advantage of wet-year (unscheduled) water diversions from the Delta and reduce diversions in dry years (Semitropic Water Storage District 2011).

In the Delta:

- **East Contra Costa County.** Located entirely within the statutory Delta, all the water suppliers that participate in this IRWMP rely upon the Delta for more than 80 percent of average-year water demands, with three water suppliers receiving 100 percent. The IRWMP priorities for reducing reliance on the Delta include expanded use of recycled water, installation of water meters, increased water conservation, and new wellhead treatment for groundwater supplies (Contra Costa Water District 2011).

In the Bay Area:

- **City and County of San Francisco.** Increased water efficiency has resulted in general decline in total consumption and per capita water use since the mid-1970s to record low levels in the state despite growth in the county's population. Recognition of the vulnerability of the city's Hetch Hetchy Reservoir and aqueduct system to earthquakes and other emergencies, San Francisco is working to diversify its local water supplies, including increased conservation, new local groundwater wells, expansion of recycled water, use of gray water, rainwater harvesting, and participation in the Bay Area Regional Desalination Project with Contra Costa Water District, East Bay Municipal Utility District, Santa Clara Valley Water District, and Zone 7 Water Agency (San Francisco Public Utilities Commission 2011).

In the Delta upper watershed:

- **American River Basin.** The IRWMP features reduced reliance on water in the Delta's American River tributaries through expanded conjunctive use operations, development of recycled water, and increased water conservation. More water will be diverted during wetter periods and made available as groundwater in drier periods, which will help increase regional water supply reliability while improving flow and temperature conditions that benefit salmon and steelhead fisheries in the lower American River (Regional Water Authority 2011).

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to implement water projects. In the 2005 round of urban water management plan submittals, this incentive increased the number of plans submitted over previous years; however, only 75 percent of agencies that should submit plans actually did as of December 31, 2006, and more than 50 percent of these failed to include required conservation or drought contingency plans (DWR 2006). In the 2010 round of urban water management plan submittals, 66 percent of the agencies required to submit plans actually did by the August 2011 deadline. One year later, this percentage had increased to 85 percent, but no assessment for completeness has been performed (DWR 2012b).

Widespread compliance with existing water management laws alone would achieve great progress in improving water supply reliability for California. Compliance with all State water efficiency and management statutes and policies, at a minimum, should be the starting point for assessing a water supplier's reasonable use of California's water. In particular, water suppliers that do not engage in efficient use of water, particularly where the implementation of proven measures and technologies are economically justifiable, locally cost effective, and do not harm other water users, should be held accountable for wasting water. The SWRCB should be encouraged to use its authority to prevent waste and unreasonable use by seeking enforcement of these requirements. The potential for this type of action was anticipated in the Water Conservation Act of 2009 (SBX7 7), which explicitly recognized that the failure of urban water suppliers to reduce urban per capita water demand consistent with the State's 20 percent by 2020 conservation targets can be used after January 2021 to establish a violation of the law for the purposes of State administrative or judicial proceedings (Water Code section 10608.8(a)(2)).

Importantly, for those who prepare them, urban water management plans and integrated regional water management plans appear to be working. As a result of these efforts and increased irrigation efficiency, the amount of water needed to meet future urban and agricultural demands has changed. Since 1980, the total volume of water used in the urban and agricultural sectors has declined. Urban areas that have implemented the strongest water conservation programs show the greatest improvements in water efficiency and the largest reductions in water use (see Figure 3-8).

Groundwater Overdraft Is an Impediment to the Coequal Goals

Groundwater is a major source of water supply for nearly every region in California and a vital component of the state's water storage system, particularly during droughts (DWR 2009). More than 40 percent of Californians rely on groundwater for part of their water supply, and many small- to moderate-sized towns and cities are entirely dependent on groundwater for their drinking water systems (DWR 2003a). The state's most significant groundwater use occurs in regions that also rely on water from the Delta watershed, including the San Joaquin Valley, Tulare Lake, Sacramento Valley, Central Coast, and South Coast (see Figures 3-9 and 3-10). The Tulare Lake region alone accounts for more than one-third of the state's total groundwater pumping (DWR 2009). Because of historical groundwater overdraft and resulting land subsidence experienced in these regions, water users switched to using surface water from the CVP and SWP when the water projects were completed in the late 1960s. However, groundwater pumping and overdraft continued to become more severe as water demands continued to exceed available supplies. Recent satellite imaging revealed that the Central Valley lost approximately 25 MAF of stored groundwater during the period of October 2003 to March 2010 (Famiglietti et al. 2011).

As a result of use continually exceeding recharge, many of California's groundwater basins are in overdraft, and groundwater levels are declining over the long term (Faunt 2009). In some areas, overdraft can lead to a permanent loss of groundwater storage. According to DWR, a groundwater basin is in a state of "critical overdraft" when continuation of present water management practices would result in significant adverse overdraft-related environmental, social, or economic impacts. DWR estimates statewide average overdraft of about 1 to 2 MAF per year (DWR 2009). Groundwater use is also increasing, and is expected to grow at a faster rate in future decades as climate change reduces the reliability of surface water deliveries and increases the potential for extended droughts (DWR 2009). Without more efficient management, the state's groundwater resources will be significantly impacted, and in severe overdraft conditions, the aquifer's capacity to store groundwater may be irretrievably lost (DWR 2003a). Improved management is also needed to take advantage of opportunities to store water underground, particularly to aid flexibility when done in coordination with improved operations in the Delta.

California has established laws, regulations, and programs to protect the quality of its groundwater resources. Despite the major importance of this water supply to California, however, the quantity of groundwater used by agencies or individuals is largely unregulated at the State level. Except for Texas, California is the only state where use of its groundwater resources is managed at the local rather than State level. The lack of State oversight means that limited and often incomplete information is available to the public about how California's groundwater basins are being managed. So little is known, that in 2003, DWR was unable to revise the designation of critically overdrafted basins in its update on California's groundwater (DWR 2003a). Lacking current information and having limited resources to complete additional investigations, DWR simply republished the list of 11 basins identified in 1980.

Trends in California's Water Use

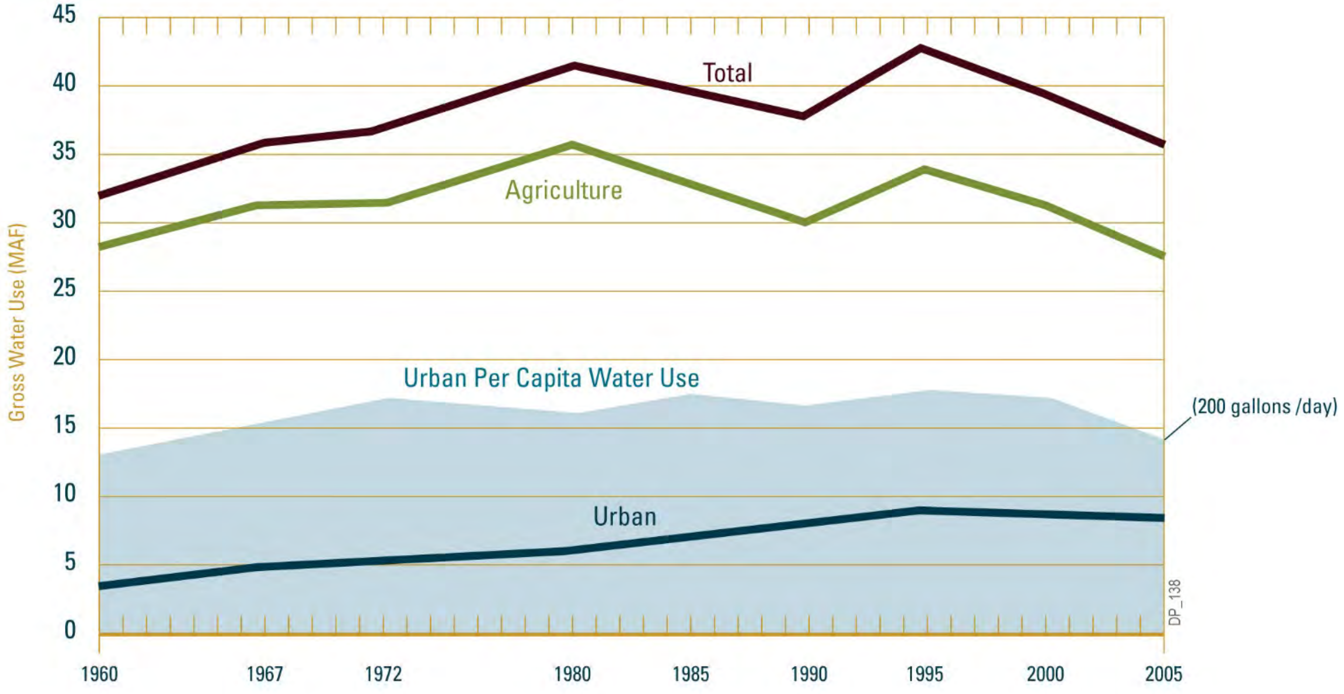

Figure 3-8

California's water use is declining, primarily due to increased water efficiency in both agricultural and urban areas. The City of Los Angeles, like many other cities, reports that it is using the same amount of water as it did over 30 years ago, even though its population has grown by more than 1 million people.

Sources: Hanak et al. 2011; adapted from DWR 2009

Critically Overdrafted Groundwater Basins

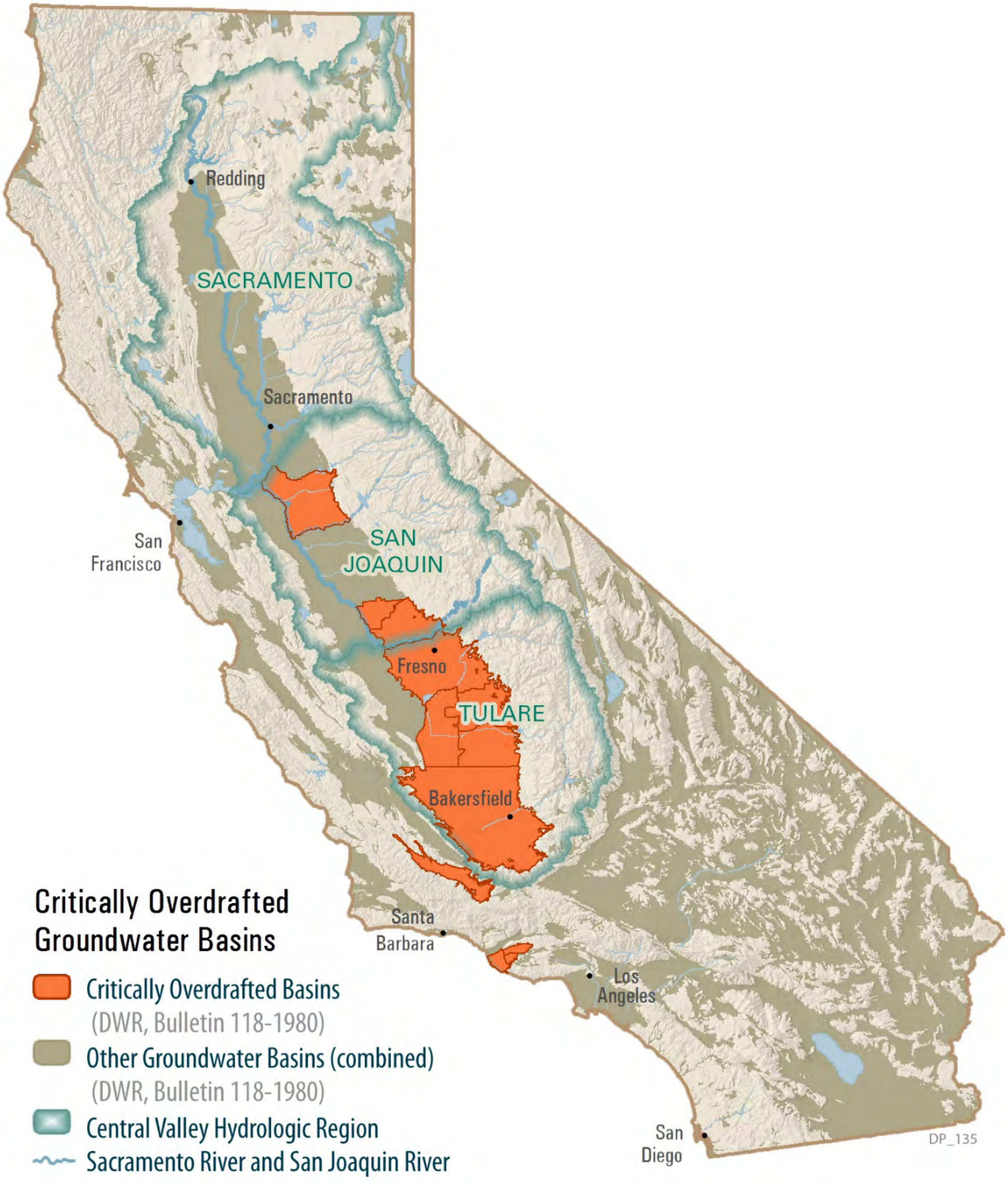

Figure 3-9

Groundwater overdraft is a critical water supply problem, especially in the Central Valley. More than 40 percent of Californians rely on groundwater for some portion of their supply, and many small- and moderate-sized communities are entirely dependent on groundwater for drinking water.

Sources: DWR 2003a; DWR 2009

San Joaquin Groundwater Pumping Is Unsustainable

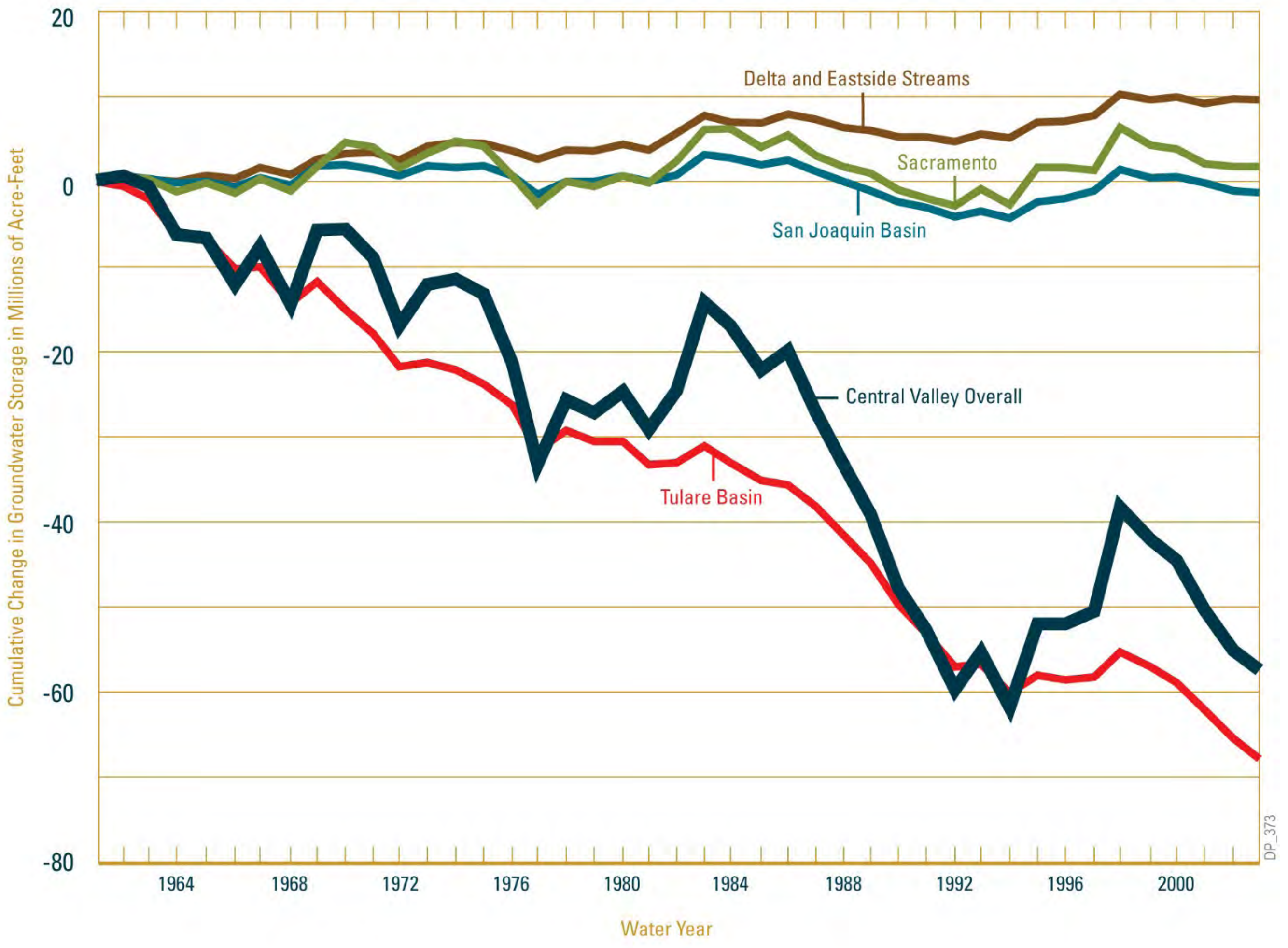

Figure 3-10

Estimated cumulative annual changes in groundwater storage in the Tulare Lake Basin due to over-pumping are more than 60 MAF since 1960. Serious land subsidence and loss of groundwater storage capacity impacts more than half of this region.

Source: Faunt 2009

Some regions appear to be making significant progress in developing sustainable groundwater management programs through regional water balances and voluntary groundwater management plans (known as AB 3030 plans), local ordinances, and court adjudications (Nelson 2011).[15] In 2009, the State created a mandatory statewide program for local reporting of groundwater elevation data, the California Statewide Groundwater Elevation Monitoring Program. This program will collect reported groundwater elevations and make the data available online.

Informed Decision Making Requires Information

One of the greatest challenges to California water management is the lack of consistent, comprehensive, and accurate estimates of actual water use by the type of use (agricultural, urban, and environmental) and by hydrologic region. The water use that is reported to the State is a combination of measured uses and estimated use that are not measured, with limited verification of actual water use. This means that California does not have a clear understanding of its water demands, the amount of water available to meet those demands, how water is being managed, and how that management can be improved to achieve the coequal goals for the Delta.

Key concerns include:

- Not all water uses are required to be monitored and measured. Many water rights were issued decades ago when water measurement was not required. Until reforms were approved by the California Legislature in 2009, water rights holders were not required to provide detailed information on water diversions and use. As a result, total diversion amounts are currently unknown and may be over-allocated in some locations or during dry periods (SWRCB 2008, SWRCB 2011, NRC 2012). Similarly, many groundwater withdrawals are not monitored or reported.
- Not all water users report data even when they are required to do so. A 2009 report prepared for the Legislature by the SWRCB on the development of a coordinated measurement database indicated that historically, about 67 percent of water permit and license holders actually report their water use information, and fewer than 35 percent of other water right claimants who are required to report actually do so (SWRCB 2009).
- SWP contractors are not required by DWR to provide data similar to that collected by Reclamation for CVP contractors. Reclamation has established best management practices for water efficiency, consistent with the federal Reclamation Reform Act and the Central Valley Project Improvement Act, and performs a "Water Needs Assessment" for each federal contractor with input from that contractor. Reclamation also requires contractors to submit an annual report that includes a full water balance (production from all sources, system losses, and changes in storage and water), and implement an effective water conservation and efficiency program based on the contractor's approved water conservation plan (Reclamation 2011b).
- SWP contract amendments in the past have not always been developed and approved in a transparent manner, and have resulted in litigation over implications for the management of the state's water supplies. In 2003, as part of a legal settlement, DWR adopted policies for how future contracts and contract amendments would be reviewed and adopted through an open and transparent process (DWR 2003b). Consistent application of this policy is important (see Appendix B).
- More detailed information on changes in groundwater levels, rates of groundwater extraction, and the location

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[15] The State encourages additional voluntary development of locally controlled groundwater monitoring programs and related management plans through AB 3030 (1992), AB 303 (2000), AB 599 (2001), and SB 1938 (2002); through the IRWMP Program (through funding provided by Propositions 13, 50, and 84); and by limiting availability of State funding for water infrastructure to those agencies that have adequate groundwater management plans in place. The State also provides technical assistance to help local agencies more efficiently and sustainably manage groundwater resources, and has identified 14 required and recommended components for groundwater plans. Prior to 2002, there were no required elements for groundwater plans.

of basins with severe and chronic overdraft is needed as a baseline for the State's water resource management efforts. Basic groundwater management data (estimates of safe yield, monitoring of changes in storage in the aquifers and water quality conditions, and identification of replenishment sources and connections with surface water supplies) need to be quantified for many areas, but especially in those regions that rely upon water from the Delta watershed (DWR 2003a). The State's goal should be to sustainably maintain and maximize long-term reliability of these groundwater supplies, with a focus on preventing significant degradation of groundwater quality (DWR 2003a, ACWA 2011).

Recent legislation has resulted in significant improvements to the State's water monitoring and reporting requirements. However, time and resources will be necessary to assess the results from these improvements, which will also serve to inform future Delta Plan updates. For example, recently enacted provisions are now being implemented for:

- Groundwater monitoring (Water Code section 10920 et seq.)
- In-Delta and statewide water diversion reporting (Water Code section 5100 et seq.)
- In-Delta enforcement investigations under the authority of the Delta Watermaster (Water Code section 85230)
- Compliance with the State's goal of achieving a 20 percent reduction in statewide urban per capita water use by 2020 (Water Code section 10608 et seq.)
- Improved reporting on agricultural water use efficiency measures (Water Code section 10608 et seq. and 10800 et seq.)

In late 2010, the SWRCB also adopted regulations requiring online reporting of water use by all water rights holders, including appropriative, riparian, and pre-1914 surface water users, and groundwater users. Since 2008, DWR, SWRCB, and the California Department of Public Health have been working to develop a coordinated database to track the urban and agricultural water use data that are provided to each agency. This tool is central to the development of a statewide integrated system for streamlined data collection and analysis that will support improved water management in California.

POLICIES AND RECOMMENDATIONS

Policies and recommendations for providing a more reliable water supply for California are based on four core strategies:

- Increase water conservation and expand local and regional supplies
- Improve groundwater management
- Improve conveyance and expand storage
- Improve water management information

Increase Water Conservation and Expand Local and Regional Supplies

Approximately 84 percent of California's water supplies come from local and regional sources, including surface runoff, groundwater, recycled water, and water made available through advanced treatment. Improved management of these resources, including water conservation and efficiency, is central to the state's ability to better match its demands to the amount of supply that is available. Over the next 30 years, the *California Water Plan Update 2009* estimates that, with the use of existing technology, the state can reduce its demands and increase its water supplies in the range of 5 to 10 MAF. This is more than enough water to meet California's projected water demands beyond 2050 and to sustain its economic vitality.

The State's constitutional principle of reasonable use and the Public Trust Doctrine form the legal foundation for California's water management policies. Importantly, along with the coequal goals, the Delta Reform Act also established a new policy for California of reducing reliance on the Delta and improving regional self-reliance in meeting California's future water supply needs. The Delta Reform Act mandates many strategies that the Delta Plan must address to improve water supply reliability for California including water efficiency and conservation, wastewater reclamation and recycling, desalination and advanced water treatment technologies, improved water conveyance, surface and groundwater storage, improved water quality, and implementation of local and regional water supply projects and coordination (see Water Code sections 85004(b), 85020(d) and (f), 85201, 85023, 85303, and 85304).

An assessment of future water supply reliability is now required in urban water management and agricultural water management plans, as well as in voluntary regional water planning documents known as IRWMPs. In areas that rely upon water from the Delta watershed, water suppliers will need to identify, evaluate, and implement locally cost-effective and technologically feasible measures that reduce their reliance on the Delta and improve regional self-reliance.

Problem Statement

The lack of participation by some water suppliers throughout California to implement laws, programs, and projects that improve water efficiency, expand local and regional water supplies, and reduce reliance on the Delta and the Delta watershed contributes to higher water demands, less water supply to meet these demands, greater pressure on the Delta ecosystem for its water, and more vulnerability to the impacts of climate change and catastrophic events. Given the Delta Reform Act mandates to improve water supply reliability for California, reduce reliance on the Delta, and improve regional self-reliance, at a minimum, all water suppliers should demonstrate full compliance with State water efficiency and management laws, goals, and regulations to demonstrate reasonable and beneficial use of the state's water resources. California's success in achieving the policy of reduced reliance on the Delta and improving regional self-reliance will be demonstrated through a significant reduction in the amount of water used or in the percentage of water used from the Delta watershed. See Appendix G for additional information regarding how to achieve reduced reliance on the Delta and improved regional self-reliance.

Policies

WR P1. Reduce Reliance on the Delta through Improved Regional Water Self-Reliance

(a) Water shall not be exported from, transferred through, or used in the Delta if all of the following apply:

(1) One or more water suppliers that would receive water as a result of the export, transfer, or use have failed to adequately

contribute to reduced reliance on the Delta and improved regional self-reliance consistent with all of the requirements listed in paragraph (1) of subsection (c);

(2) That failure has significantly caused the need for the export, transfer, or use; and

(3) The export, transfer, or use would have a significant adverse environmental impact in the Delta.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action to export water from, transfer water through, or use water in the Delta, but does not cover any such action unless one or more water suppliers would receive water as a result of the proposed action.

(c) (1) Water suppliers that have done all of the following are contributing to reduced reliance on the Delta and improved regional self-reliance and are therefore consistent with this policy:

(A) Completed a current Urban or Agricultural Water Management Plan (Plan) which has been reviewed by the California Department of Water Resources for compliance with the applicable requirements of Water Code Division 6, Parts 2.55, 2.6, and 2.8;

(B) Identified, evaluated, and commenced implementation, consistent with the implementation schedule set forth in the Plan, of all programs and projects included in the Plan that are locally cost effective and technically feasible which reduce reliance on the Delta; and

(C) Included in the Plan, commencing in 2015, the expected outcome for measurable reduction in Delta reliance and improvement in regional self-reliance. The expected outcome for measurable reduction in Delta reliance and improvement in regional self-reliance shall be reported in the Plan as the reduction in the amount of water used, or in the percentage of water used, from the Delta watershed. For the purposes of reporting, water efficiency is considered a new source of water supply, consistent with Water Code section 1011(a).

(2) Programs and projects that reduce reliance could include, but are not limited to, improvements in water use efficiency, water recycling, stormwater capture and use, advanced water technologies, conjunctive use projects, local and regional water supply and storage projects, and improved regional coordination of local and regional water supply efforts.

23 CCR Section 5003

NOTE: Authority cited: Section 85210(i), Water Code.

Reference: Sections 10608, 10610.2, 10610.4, 10801, 10802, 85001(c), 85004(b), 85020(a), 85020(d), 85020(h), 85021, 85022(d)(1), 85022(d)(5), 85023, 85054, 85300, 85302(d), 85303, and 85304, Water Code.

Recommendations

WR R1. Implement Water Efficiency and Water Management Planning Laws

All water suppliers should fully implement applicable water efficiency and water management laws, including urban water management plans (Water Code section 10610 et seq.); the 20 percent reduction in statewide urban per capita water usage by 2020 (Water Code section 10608 et seq.); agricultural water management plans (Water Code section 10608 et seq. and 10800 et seq.); and other applicable water laws, regulations, or rules.

WR R2. Require SWP Contractors to Implement Water Efficiency and Water Management Laws

The California Department of Water Resources should include a provision in all State Water Project contracts, contract amendments, contract renewals, and water transfer agreements that requires the implementation of all State water efficiency and water management laws, goals, and regulations, including compliance with Water Code section 85021.

WR R3. Compliance with Reasonable and Beneficial Use

The State Water Resources Control Board should evaluate all applications and petitions for a new water right or a new or changed point of diversion, place of use, or purpose of use that would result in new or increased long-term average use of water from the Delta watershed for consistency with the constitutional principle of reasonable and beneficial use. The State Water Resources Control Board should conduct its evaluation consistent with Water Code sections 85021, 85023, 85031, and other provisions of California law. An applicant or petitioner should submit to the State Water Resources Control Board sufficient information to support findings of consistency, including, as applicable, its urban water management plan, agricultural water management plan, and environmental documents prepared pursuant to the California Environmental Quality Act.

WR R4. Expanded Water Supply Reliability Element

Water suppliers that receive water from the Delta watershed should include an expanded water supply reliability element, starting in 2015, as part of the update of an urban water management plan, agricultural water management plan, integrated water management plan, or other plan that provides equivalent information about the supplier's planned investments in water conservation and water supply development. The expanded water supply reliability element should detail how water suppliers are reducing reliance on the Delta and improving regional self-reliance consistent with Water Code section 85201 through investments in local and regional programs and projects, and should document the expected outcome for a measurable reduction in reliance on the Delta and improvement in regional self-reliance. At a minimum, these plans should include a plan for possible interruption of water supplies for up to 36 months due to catastrophic events impacting the Delta, evaluation of the regional water balance, a climate change vulnerability assessment, and an evaluation of the extent to which the supplier's rate structure promotes and sustains efficient water use.

WR R5. Develop Water Supply Reliability Element Guidelines

The California Department of Water Resources, in consultation with the Delta Stewardship Council, the State Water Resources Control Board, and others, should develop and approve, by December 31, 2014, guidelines for the preparation of a water supply reliability element so that water suppliers can begin implementation of WR R4 by 2015.

WR R6. Update Water Efficiency Goals

The California Department of Water Resources and the State Water Resources Control Board should establish an advisory group with other State agencies and stakeholders to identify and implement measures to reduce impediments to achievement of statewide water conservation, recycled water, and stormwater goals by 2014. This group should evaluate and recommend updated goals for additional water efficiency and water resource development by 2018. Issues such as water distribution system leakage should be addressed. Evaluation should include an assessment of how regions are achieving their proportional share of these goals.

WR R7. Revise State Grant and Loan Priorities

The California Department of Water Resources, the State Water Resources Control Board, the California Department of Public Health, and other agencies, in consultation with the Delta Stewardship Council, should revise State grant and loan ranking criteria by December 31, 2013, to be consistent with Water Code section 85021 and to provide a priority for water suppliers that includes an expanded water supply reliability element in their adopted urban water management plans, agricultural water management plans, and/or integrated regional water management plans.

WR R8. Demonstrate State Leadership

All State agencies should take a leadership role in designing new and retrofitted State-owned and -leased facilities, including buildings and California Department of Transportation facilities, to increase water efficiency, use recycled water, and incorporate stormwater runoff capture and low-impact development strategies.

Improve Groundwater Management

Groundwater is the source, on average, of 20 percent of California's urban and agricultural water supplies. The state's most significant groundwater use occurs in regions that also rely upon water from the Delta watershed. In many of these groundwater basins, more water is pumped than is recharged, and groundwater levels are declining over the long term. The ***California Water Plan Update 2009*** estimates that the state, on average, overdrafts its groundwater basins by about 1 to 2 MAF per year and that the level of unsustainable groundwater pumping is increasing.

Problem Statement

The continued existence of major California groundwater basins in a chronic condition of overdraft combined with key regions of the state that depend on water from the Delta watershed and have poor groundwater practices, including unsustainable groundwater pumping, water quality contamination, irreversible loss of groundwater storage, and no groundwater plan for addressing these problems, is a major impediment to the achievement of the coequal goals.

Policies

No policies with regulatory effect are included in this section.

Recommendations

WR R9. Update Bulletin 118, California's Groundwater Plan

The California Department of Water Resources, in consultation with the Bureau of Reclamation, U.S. Geological Survey, the State Water Resources Control Board, and other agencies and stakeholders, should update Bulletin 118 information using field data, California Statewide Groundwater Elevation Monitoring (CASGEM), groundwater agency reports, satellite imagery, and other best available science by December 31, 2014, so that this information can be included in the next California Water Plan Update and be available for inclusion in 2015 urban water management plans and agricultural water management plans. The Bulletin 118 update should include a systematic evaluation of major groundwater basins to determine sustainable yield and overdraft status; a projection of California's groundwater resources in 20 years if current groundwater management trends remain unchanged; anticipated impacts of climate change on surface water and groundwater resources; and recommendations for State, federal, and local actions to improve groundwater management. In addition, the Bulletin 118 update should identify groundwater basins that are in a critical condition of overdraft.

WR R10. Implement Groundwater Management Plans in Areas that Receive Water from the Delta Watershed

Water suppliers that receive water from the Delta watershed and that obtain a significant percentage of their long-term average water supplies from groundwater sources should develop and implement sustainable groundwater management plans that are consistent with both the required and recommended components of local groundwater management plans identified by the California Department of Water Resources Bulletin 118 (Update 2003) by December 31, 2014.

WR R11. Recover and Manage Critically Overdrafted Groundwater Basins

Local and regional agencies in groundwater basins that have been identified by the California Department of Water Resources as being in a critical condition of overdraft should develop and implement a sustainable groundwater management plan, consistent with both the required and recommended components of local groundwater management plans identified by the California Department of Water Resources Bulletin 118 (Update 2003), by December 31, 2014. If local or regional agencies fail to develop and implement these plans, the State Water Resources Control Board should take action to determine if the continued overuse of a groundwater basin constitutes a violation of the State's Constitution Article X, Section 2, prohibition on unreasonable use of water and whether a groundwater adjudication is necessary to prevent the destruction of or irreparable injury to the quality of the groundwater, consistent with Water Code sections 2100 and 2101.

Improve Conveyance and Expand Storage

The greatest conflicts between the water needs of people and fish within the Delta occur during dry years. That is when the least amount of water is flowing into the Delta and, historically, when exports have been a much larger percentage of Delta inflows compared with wet years. The timing and pattern of Delta diversions must be shifted so that more water can be exported during wet years, when there is significantly more water available for diversion, and less is taken in dry years, when the water is needed for in-Delta water quality and ecosystem protections.

The ability to export larger amounts of water from the Delta during wet years will require improved conveyance to increase operational flexibility as well as more storage both north and south of the Delta so that this water can be captured, stored, and ultimately delivered to meet the water needs of both people and fish. With these improvements, Delta operations and, importantly, Delta export deliveries will become more predictable.

As an interim step toward increasing California's water supply reliability, the State should identify, prioritize, and implement smaller and more incremental operational, conveyance, and storage improvements (such as expanding existing facilities or constructing new ones) that can be accomplished quickly, preferably within the next 5 to 10 years.

Problem Statement

The state's interconnected network of surface and groundwater storage is insufficient in volume, conveyance capacity, and flexibility to achieve the coequal goals. The completion of the BDCP and the implementation of major new surface and groundwater storage facilities are needed but may take many years to implement, which will require more near-term actions to improve Delta operations and reduce the state's vulnerability to potential disruptions in water exports from the Delta due to floods and earthquakes or the need for additional regulatory protections for the environment.

Policies

No policies with regulatory effect are included in this section. See Appendix A, The Delta Stewardship Council's Role Regarding Conveyance.

Recommendations

WR R12. Complete Bay Delta Conservation Plan

The relevant federal, State, and local agencies should complete the Bay Delta Conservation Plan, consistent with the provisions of the Delta Reform Act, and receive required incidental take permits by December 31, 2014.

WR R13. Complete Surface Water Storage Studies

The California Department of Water Resources should complete surface water storage investigations of proposed off-stream surface storage projects by December 31, 2012, including an evaluation of potential additional benefits of integrating operations of new storage with proposed Delta conveyance improvements, and recommend the critical projects that need to be implemented to expand the state's surface storage.

WR R14. Identify Near-term Opportunities for Storage, Use, and Water Transfer Projects

The California Department of Water Resources, in coordination with the California Water Commission, Bureau of Reclamation, State Water Resources Control Board, California Department of Public Health, the Delta Stewardship Council, and other agencies and stakeholders, should conduct a survey to identify projects throughout California that could be implemented within the next 5 to 10 years to expand existing surface and groundwater storage facilities, create new storage, improve operation of existing Delta conveyance facilities, and enhance opportunities for conjunctive use programs and water transfers in furtherance of the coequal goals. The California Water Commission should hold hearings and provide recommendations to the California Department of Water Resources on priority projects and funding.

WR R15. Improve Water Transfer Procedures

The California Department of Water Resources and the State Water Resources Control Board should work with stakeholders to identify and recommend measures to reduce procedural and administrative impediments to water transfers and protect water rights and environmental resources by December 31, 2016. These recommendations should include measures to address potential issues with recurring transfers of up to 1 year in duration and improved public notification for proposed water transfers.

Improved Water Management Information

One of the greatest challenges to improved management of California's water supplies is the lack of consistent, comprehensive, and accurate estimates of actual water use in the state, both by sector of use (agricultural, urban, and environmental) and by regions within the state. The sheer number of water management agencies in California is a key logistical factor. Current data reported to various State agencies is a combination of measured uses and estimated uses, with limited verification of actual water use. This means that California does not have a clear understanding of its water demands, the amount of water available to meet those demands, how water is being managed, and how that management can be improved to achieve the coequal goals.

Problem Statement

Accurate, timely, consistent, and transparent information on the management of California water supplies and beneficial uses is an important tool used in the achievement of the coequal goals. The State needs sufficient information to assess the current reliability of its water supplies or to meaningfully measure progress toward achievement of more reliable water supplies for California.

Policies

The appendices referred to in the policy language below are included in Appendix B of the Delta Plan.

WR P2. Transparency in Water Contracting

(a) The contracting process for water from the State Water Project and/or the Central Valley Project must be done in a publicly transparent manner consistent with applicable policies of the California Department of Water Resources and the Bureau of Reclamation referenced below.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers the following:

  (1) With regard to water from the State Water Project, a proposed action to enter into or amend a water supply

or water transfer contract subject to California Department of Water Resources Guidelines 03-09 and/or 03-10 (each dated July 3, 2003), which are attached as Appendix 2A; and

(2) With regard to water from the Central Valley Project, a proposed action to enter into or amend a water supply or water transfer contract subject to section 226 of P.L. 97-293, as amended or section 3405(a)(2)(B) of the Central Valley Project Improvement Act, Title XXXIV of Public Law 102-575, as amended, which are attached as Appendix 2B, and Rules and Regulations promulgated by the Secretary of the Interior to implement these laws.

23 CCR Section 5004
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85021, 85300, and 85302, Water Code.

Recommendations

WR R16. Supplemental Water Use Reporting

The State Water Resources Control Board should require water rights holders submitting supplemental statements of water diversion and use or progress reports under their permits or licenses to report on the development and implementation of all water efficiency and water supply projects and on their net (consumptive) use.

WR R17. Integrated Statewide System for Water Use Reporting

The California Department of Water Resources, in coordination with the State Water Resources Control Board, California Department of Public Health, California Public Utilities Commission, California Energy Commission, Bureau of Reclamation, California Urban Water Conservation Council, and other stakeholders, should develop a coordinated statewide system for water use reporting. This system should incorporate recommendations for inclusion of data needed to better manage California's water resources. The system should be designed to simplify reporting; reduce the number of required reports where possible; be made available to the public online; and be integrated with the reporting requirements for the urban water management plans, agricultural water management plans, and integrated regional water management plans. Water suppliers that export water from, transfer water through, or use water in the Delta watershed should be full participants in the database.

WR R18. California Water Plan

The California Department of Water Resources, in consultation with the State Water Resources Control Board and other agencies and stakeholders, should evaluate and include in the next and all future California Water Plan updates information needed to track water supply reliability performance measures identified in the Delta Plan, including an assessment of water efficiency and new water supply development, regional water balances, improvements in regional self-reliance, reduced regional reliance on the Delta, and reliability of Delta exports, and an overall assessment of progress in achieving the coequal goals.

WR R19. Financial Needs Assessment

As part of the California Water Plan Update, the California Department of Water Resources should prepare an assessment of the state's water infrastructure. This should include the costs of rehabilitating/replacing existing infrastructure, an assessment of the costs of new infrastructure, and an assessment of needed resources for monitoring and adaptive management for these projects. The California Department of Water Resources should also consider a survey of agencies that may be planning small-scale projects (such as storage or conveyance) that improve water supply reliability.

Timeline for Implementing Policies and Recommendations

Figure 3-11 lays out a timeline for implementing the policies and recommendations described in the previous section. The timeline emphasizes near-term and intermediate-term actions.

Timeline for Implementing Policies and Recommendations

TIMELINE

CHAPTER 3: Reliable Water Supply

	ACTION (REFERENCE #)	LEAD AGENCY(IES)	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025
POLICIES	Reduce reliance on the Delta through improved regional water self-reliance (WR P1)	Water suppliers	●	●
	Transparency in water contracting (WR P2)		●	●
RECOMMENDATIONS	Implement water efficiency and water management planning laws (WR R1)	Water suppliers	●	●
	Require State Water Project contractors to implement water efficiency and water management laws (WR R2)	DWR	●	●
	Compliance with reasonable and beneficial use (WR R3)	SWRCB	●	●
	Expanded water supply reliability element (WR R4)	Water suppliers receiving Delta water	●	
	Develop water supply reliability element guidelines (WR R5)	DWR	●	
	Update water efficiency goals (WR R6)	DWR and SWRCB	●	●
	Revise State grant and loan priorities (WR R7)	DWR, SWRCB, and DPH	●	
	Demonstrate State leadership (WR R8)	State agencies	●	●
	Update Bulletin 118, California's Groundwater Plan (WR R9)	DWR	●	●
	Implement groundwater management plans in areas that receive water from the Delta watershed (WR R10)	Water suppliers receiving Delta water and uses groundwater	●	
	Recover and manage critically overdrafted groundwater basins (WR R11)	Local and regional agencies	●	●
	Complete Bay Delta Conservation Plan (WR R12)	Federal, State, and local agencies	●	●
	Complete surface water storage studies (WR R13)	DWR	●	
	Identify near-term opportunities for storage, use, and water transfer projects (WR R14)	DWR	●	
	Improve water transfer procedures (WR R15)	DWR	●	
	Supplemental water use reporting (WR R16)	SWRCB	●	
	Integrated statewide system for water use reporting (WR R17)	DWR	●	●
	California Water Plan (WR R18)	DWR	●	
	Financial needs assessment (WR R19)	DWR	●	●

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Agency Key:

Council: Delta Stewardship Council
DPH: California Department of Public Health
DWR: California Department of Water Resources
RWQCB: Regional Water Quality Control Board(s)
SWRCB: State Water Resources Control Board
Water suppliers: refers to both urban and agricultural water suppliers

Figure 3-11

Science and Information Needs

An improved understanding of the state's hydrologic systems, patterns of water use, and effects of climate change, especially within the Delta watershed and areas that receive water from the Delta, is essential to improving the management of California's water supplies to achieve the coequal goals. Key areas of needed research include:

- Improved projections for and measurement of surface water flows (amounts, timing, quality) and how they may be impacted by environmental regulations, changing land uses, and climate change
- Improved water supply and demand forecasting models that incorporate vulnerability to extreme events (droughts, floods, earthquakes) and account for the impacts of climate change
- Improved methods for downscaling climate change models (including dynamic downscaling) and improved models for water scenario planning that incorporates these data
- Improved information on effective watershed management actions to restore and enhance capacity of rural and urban landscapes to process stormwater for water quality and water supply benefits
- Improved models for assessing the interaction between water management scenarios in the Delta and ecosystem function, including implications of revised instream flow requirements on inflows to the Delta and revised wet year/dry year export scenarios
- Improved information on changing water use patterns in response to urban and agricultural water efficiency measures, including water pricing, and implications for future water demands
- Improved characterization of groundwater basins and subbasins, and improved estimates of groundwater supplies (amounts, quality)
- Improved models of aquifer and surface-groundwater relationships, which include the effects of climate change on evaporation, runoff, groundwater recharge, subsurface interactions, and the implications of these effects for safe yield and implementation of conjunctive use and water transfer programs

Issues for Future Evaluation and Coordination

Additional areas of interest and concern related to water supply and the Delta may deserve consideration in the development of future Delta Plan updates, including:

- **Delta water delivery predictability.** A Delta Delivery Predictability Index should be developed that depicts, by hydrologic year types, the estimated streamflows entering the Delta and suggested levels of water exports that would be consistent with in-Delta and ecosystem protections. As part of the index, a system for tracking the use of stored Delta water also should be developed. The index will lead to a better understanding of how water exported and stored during wet years would be available to urban and agricultural users during dry years to offset reduced exports. This information is key to better understanding how investments in new storage and improved conveyance contribute to improved reliability of California's water supplies.
- **Performance measures for reduced reliance on the Delta.** The Delta Plan identifies two core measures for assessing progress in reducing reliance on the Delta: (1) a significant reduction in the amount of water used from the Delta watershed, or (2) a significant reduction in the percentage of water used from the Delta watershed. The Council will collaborate with DWR, SWRCB, and stakeholders to develop a standardized method or methods by which progress to reduce reliance on the Delta and improve regional self-reliance should be reported (1) in the urban and agricultural water management plans; (2) in IRWMPs; and (3) in the California Water Plan. Potential additional measures should be identified and evaluated that will benefit the amount of water, quality of water, and timing of flows in and

through the Delta, and contribute to reduced reliance on the Delta and improving regional self-reliance consistent with Water Code section 85021.

- **Evaluation of urban and agricultural water management plans.** The Council will work with DWR and the State Legislature to identify resources and secure authority, if necessary, to conduct further evaluation of water management information contained in urban and agricultural water management plans. The goal of these actions is to improve knowledge about water management in California and, specifically, to facilitate the aggregation and evaluation of water management data over time to gauge success toward reducing reliance on the Delta, increasing regional self-reliance, and achieving the coequal goals.
- **Integrated water resource management.** The value of integrated regional water management planning is widely recognized, but information on how to implement effective integrated water management projects is not well understood. The number of conjunctive management programs that combine green urban design, flood control, stormwater infiltration, water conservation, recycled water, and groundwater elements are increasing. Information about the successful integration of water management infrastructure needs to be shared and consideration given as to how to effectively promote implementation of these integrated strategies.
- **Agricultural and urban water efficiency.** Improved demand management through urban and agricultural water conservation and efficiency is the fastest and least expensive strategy for making more water available to the Delta through inflows and reducing the pressure to export more water from the Delta. Additional best management practices should be identified and promoted, including evaluation of new water conservation-based rate structures and how they contribute to water savings while maintaining more stable revenue for water suppliers.
- **Delta Watermaster.** The Delta Watermaster is in the process of completing an assessment of potential illegal water diversions within the Delta. This assessment should be expanded to evaluate illegal water diversions throughout the Delta watershed.
- **Reoperation of upstream reservoirs.** DWR is working with USACE and other agencies to develop a coordinated proposal for the reoperation of reservoirs above the Delta to address the impacts of climate change on flood protection and water supply operations. This proposal should include consideration of improved watershed management actions that will also help attenuate flood flows as well as improve ecosystem functions and water supply availability.

Performance Measures

Development of informative and meaningful performance measures is a challenging task that will continue after adoption of the Delta Plan. Performance measures need to be designed to capture important trends and to address whether specific actions are producing expected results. Efforts to develop and track performance measures in complex and large-scale systems like the Delta are commonly multiple-year endeavors. The recommended output and outcome performance measures listed below are provided as examples and subject to refinement as time and resources allow. Final administrative performance measures are listed in Appendix E and will be tracked as soon as the Delta Plan is completed.

Output Performance Measures

- Water suppliers that receive water from the Delta watershed have documented the expected outcome for a measureable reduction in reliance on the Delta and improvement in regional self-reliance. (WR R1, WR R4)
- Progress made in achieving existing water conservation and water supply performance goals, and setting expanded future goals for local, regional, and statewide

water conservation, water use efficiency, and water supply development. (WR R6)

- Information in updated Bulletin 118 is included in the next (2013) California Water Plan Update and in the 2015 urban water management plans and agricultural water management plans. (WR R9)

Outcome Performance Measures

- Progress toward increasing local and regional water supplies, measured by the amount of additional supplies made available (reported in 5-year increments from 2000). (WR P1)
- Progress toward meeting California's conservation goal of achieving a 10 percent reduction in statewide urban per capita water usage by 2015 and a 20 percent reduction by 2020. (WR R1)
- Progress toward improved reliability of Delta water exports and reductions in the vulnerability of Delta exports to disruption. (WR R12, ER P1, RR P1)
- Progress toward increasing the predictability of water deliveries from the Delta in a variety of water year types. (WR R12, WR R14)
- Progress toward achieving California's goal for the increased use of stormwater runoff of at least 500,000 acre-feet per year by 2020 and by at least 1 MAF per year by 2030. (WR R6)

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CHAPTER 4

Protect, Restore, and Enhance the Delta Ecosystem

ABOUT THIS CHAPTER

This chapter describes the Sacramento-San Joaquin Delta (Delta) ecosystem and the factors that affect and too often degrade it. It proposes policies and recommendations for restoring the Delta ecosystem organized into five core strategies to achieve the coequal goals of the Delta Reform Act:

- Create more natural functional flows
- Restore habitat
- Improve water quality to protect the ecosystem
- Prevent introduction of and manage nonnative species impacts
- Improve hatcheries and harvest management

These core strategies form the basis of the five policies and nine recommendations found at the end of the chapter.

RELEVANT LEGISLATION

The coequal goals for the Delta (Water Code section 85054) are relevant to ecosystem restoration:

> *"Coequal goals" means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.*

Eight objectives in Water Code section 85020 are inherent in the coequal goals. Section 85020(a), (c), and (e) are relevant to this chapter:

> *85020 The policy of the State of California is to achieve the following objectives that the Legislature declares are inherent in the coequal goals for management of the Delta:*
>
> > *(a) Manage the Delta's water and environmental resources and the water resources of the state over the long term.*
> >
> > *(c) Restore the Delta ecosystem, including its fisheries and wildlife, as the heart of a healthy estuary and wetland ecosystem.*
> >
> > *(e) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.*

The coequal goals and inherent objectives seek broad protection of the Delta. Achievement of these broad goals and objectives requires implementation of specific strategies. Water Code sections 85022 and 85302 provide direction on the implementation of specific measures to promote the coequal goals and inherent objectives related to the Delta ecosystem restoration.

> *85022(d)(5) Develop new or improved aquatic and terrestrial habitat and protect existing habitats to advance the goal of restoring and enhancing the Delta ecosystem.*
>
> > *(6) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.*
>
> *85302(c) The Delta Plan shall include measures that promote all of the following characteristics of a healthy Delta ecosystem.*
>
> > *(1) Viable populations of native resident and migratory species.*
> >
> > *(2) Functional corridors for migratory species.*
> >
> > *(3) Diverse and biologically appropriate habitats and ecosystem processes.*
> >
> > *(4) Reduced threats and stresses on the Delta ecosystem.*
> >
> > *(5) Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations.*
>
> *85302(d) The Delta Plan shall include measures to promote a more reliable water supply that address all of the following:*
>
> > *(1) Meeting the needs for reasonable and beneficial uses of water.*
> >
> > *(3) Improving water quality to protect human health and the environment.*
>
> *85302(e) The following subgoals and strategies for restoring a healthy ecosystem shall be included in the Delta Plan.*
>
> > *(1) Restore large areas of interconnected habitats within the Delta and its watershed by 2100.*
> >
> > *(2) Establish migratory corridors for fish, birds, and other animals along selected Delta river channels.*
> >
> > *(3) Promote self-sustaining, diverse populations of native and valued species by reducing the risk of take and harm from invasive species.*
> >
> > *(4) Restore Delta flows and channels to support a healthy estuary and other ecosystems.*
> >
> > *(5) Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals.*
> >
> > *(6) Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds.*

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CHAPTER 4

Protect, Restore, and Enhance the Delta Ecosystem

In the Delta Reform Act, the goal of protecting, restoring, and enhancing the Delta ecosystem is coequal to the goal of providing a more reliable water supply for California. Both must be accomplished while protecting and enhancing the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

Some past land and water uses have put these goals in conflict. For example, reliable water supplies have been associated with artificially stabilized flows and a complex human-made system of infrastructure that includes dams, levees, and channelized rivers and sloughs. Yet healthy rivers and estuaries, and the native species that live in them depend on naturally variable water flows and a dynamic landscape. Many native species also depend on wetlands that have been drained for farming and other human uses.

Despite these conflicts, the Delta Stewardship Council (Council) must work to achieve the goal of protecting, restoring, and enhancing the Delta ecosystem. Inherent in that goal is the objective to "restore the Delta ecosystem, including its fisheries and wildlife, as the heart of a healthy estuary and wetland ecosystem" (Water Code section 85020(c)). (See sidebar, What Does It Mean to Achieve the Goal of Protecting, Restoring, and Enhancing the Delta Ecosystem?)

The Council envisions a future in which the Delta ecosystem has the following characteristics:

- Native species, including algae and other plants, invertebrates, fish, birds, and other wildlife, are self-sustaining and persistent.
- The tidal channels and bays in the Delta and Suisun Marsh connect with freshwater creeks, upland grasslands, and woodlands.
- The Sacramento and San Joaquin rivers and other Delta tributaries include reaches where streams are free to meander and connect seasonally to functional floodplains.
- Habitats for resident and rearing migratory fish, birds, and upland wildlife are connected by migratory corridors, including areas with high-quality cover and feeding opportunities.
- More natural variations in water flows and conditions make aquatic habitats, tidal marshes, and floodplains more dynamic, encourage survival of native species, and resist invasions by weeds and animal pests.
- The ecosystem is resilient enough to absorb and adapt to current and future effects of multiple stressors without significant declines in ecosystem services.
- The Delta will provide more reliable water supplies, in part because survival of its wildlife, fish, and plants do not require extraordinary regulatory protection.
- Californians recognize and celebrate the Delta's unique natural resource values through wildlife observation, angling, waterfowl hunting, and other outdoor recreation.

This future Delta will differ from the Delta that greeted the first Californians and will probably be different from the current ecosystem. Not every species or natural area now found in the Delta may persist through the changes ahead, including climate change, but Californians' use and management of the Delta will be directed and coordinated to sustain conditions that make species' survival more likely while maintaining the many other benefits provided by the Delta ecosystem.

WHAT DOES IT MEAN TO ACHIEVE THE GOAL OF PROTECTING, RESTORING, AND ENHANCING THE DELTA ECOSYSTEM?

Achieving the coequal goal of ecosystem protection, restoration, and enhancement means successfully establishing a resilient, functioning estuary and surrounding terrestrial landscape capable of supporting viable populations of native resident and migratory species with diverse and biologically appropriate habitats, functional corridors, and ecosystem processes.

For this purpose, the term "restoration" is defined in Water Code section 85066 as follows:

> *"the application of ecological principles to restore a degraded or fragmented ecosystem and return it to a condition in which its biological and structural components achieve a close approximation of its natural potential, taking into consideration the physical changes that have occurred in the past and the future impact of climate change and sea level rise."*

Restoration actions may include restoring interconnected habitats within the Delta and its watershed, restoring more natural Delta flows, or improving ecosystem water quality.

"Protection" means preventing harm to the ecosystem, which could include preventing the conversion of existing habitat, the degradation of water quality, irretrievable conversion of lands suitable for restoration, or the spread of invasive nonnative species.

"Enhancement" means improving existing desirable habitat and natural processes. Enhancement might include flooding the Yolo Bypass more often to support native species, or to expand or better connect existing habitat areas. Enhancement includes many fish and wildlife management practices, such as managing wetlands for waterfowl production or shorebird habitat, installing fish screens to reduce entrainment of fish at water diversions, or removing barriers that block migration of fish to upstream spawning habitats.

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A Restored Delta Ecosystem Is Key to a Reliable Water Supply

Delta water supplies can be more reliable only when the Delta ecosystem is restored. The water projects that rely on the Delta were developed without contemporary understanding of the Delta's ecology or anticipation of the value that Californians now place on a healthy environment. As the effects of the projects on the Delta ecosystem became apparent, a series of adjustments in their operation has been put in place. Each adjustment affected the water diversions, altering volume and timing to reduce damage, but without fully mitigating harm to the Delta ecosystem. The perilous condition of salmon, delta smelt, and other species remains a key limit on project operations. Only as these populations recover will water project operations become more flexible and reliable.

To restore the Delta ecosystem, Californians will need to use water management facilities in new ways. Reservoirs will need to hold and release water for ecosystem purposes as well as for water users. Storage and the development of alternative supplies will be needed to help reduce reliance on the Delta and improve regional self-reliance. Multipurpose bypasses and levees will need to provide habitat while also controlling flooding. Channels and water controls will need to be able to deliver water for habitats as well as for farms and cities. Modern water diversions will need to protect fish while providing reliable water supplies. For these reasons, restoring the Delta ecosystem will require new investment in water facilities and alternative supplies, not just regulation of water project operations or restoration of habitats for fish and wildlife. Other actions undertaken to protect the ecosystem can also benefit water users; for example, vigilance in preventing invasive species introduction can avoid future costs to manage mussel infestations in pipelines or other water structures. Tradeoffs may be necessary as we better match demands to the supply available, consistent with ecosystem protection, and match our expectations about the ecosystem to the changing climate.

A restored Delta ecosystem is also important to the Delta's future as an attractive place to live, work, and recreate. Water flows are important not just to water exporters, fish, and aquatic environments, but also to the Delta's municipal, industrial, and agricultural waters users, who will need consideration as system changes are planned and implemented. Restoration actions will require careful design so they are attuned to local needs: locating habitats to minimize conflicts with existing and planned uses; working with farmers by promoting wildlife-friendly farming; providing buffers between wildlife areas and farms; working with landowners regarding how to manage restored wildlife populations on or near their lands; and improving opportunities for outdoor recreation, including boating, angling, and hunting, that are enjoyed by residents and also attract visitors. Integrating habitat improvements when levees are rebuilt or flood channels are improved can draw new sources of funds to strengthen the Delta flood control system. In essence, a systems approach that recognizes tradeoffs and the value of balance will be necessary for California to achieve the coequal goals.

The Delta Ecosystem, Past and Present

In the Delta, the Central Valley's great rivers—the Sacramento from the north and San Joaquin from the south—join the Cosumnes, Mokelumne, and Calaveras here in a vast and complex estuary influenced by tides and river currents (see Figure 4-1).

Before the early 1800s, the rivers flowed through approximately 400,000 acres of tidal wetlands and other aquatic habitats that connected with several hundred thousand acres of nontidal wetlands and riparian forest. Flows of the Delta's rivers and tidal channels varied by season and year-to-year, sometimes pouring from the Sierra in great floods whose fresh waters overflowed wetlands and floodplains, and at other times declining as droughts shriveled rivers and brackish tidewaters pushed inland. To the west, the rivers joined to discharge through marsh-fringed Suisun Bay to the Carquinez Straight, San Francisco Bay, and the Pacific Ocean.

The Delta's historical landscape also varied from north to south (see Figure 4-2). In the north Delta, flood basins occurred where the Sacramento River intertwined with tidal channels. A vast area of freshwater wetlands dominated by tules transitioned into tidal wetlands. Shallow perennial ponds and lakes, broad riparian forests along natural levees, and seasonal wetlands at the upland edge were also common. The central Delta was characterized by large, tidal islands that flooded during spring tides (or more frequently) intersected by networks of branching tidal channels. Channel banks were low and covered by the willows, grasses, sedges, shrubs, and ferns that also grew in island interiors. The south Delta contained a complex network of channels formed predominantly by riverine processes. The floodplain comprised emergent wetlands, perennial and seasonal ponds, willow thickets, and seasonal wetlands. Driftwood and other woody debris filled some channels, likely from riparian forest along the San Joaquin River's natural levees.

Historical records show a rich and complex Delta with habitats supporting diverse and abundant native plants and animals (Grossinger et al. 2010, Whipple et al. 2010, Whipple 2011). Some fish, including smelt, schooled in the open waters of the western Delta's bays and channels, moving east when brackish water intruded from San Francisco Bay. Other resident wildlife and plants also prospered: rails in tidal and tule marshes, giant garter snakes in freshwater wetlands and ponds, and riparian brush rabbits and wood rats in willow thickets and riparian forests. Each fall, salmon and steelhead, drawn by the swelling Sacramento and San Joaquin rivers, migrated inland from the ocean and navigated upstream to spawning areas in their tributaries. As river flows receded, their young, emerging from these tributaries' spawning gravel, would return downstream and shelter in driftwood-lined eddies or undercut riverbanks and feed in Delta sloughs, marshes, and floodplains before returning to the sea. Waterfowl, cranes, and shorebirds migrated through the Delta along a north-south route that stretched from the Arctic to Mexico or beyond. Songbirds followed a similar path through riparian woodlands that connected from the Sacramento Valley through the Delta to the San Joaquin Valley.

To immigrants arriving in the nineteenth century, the Delta and Central Valley appeared a wild and dangerous place that had to be "reclaimed" to support the agricultural way of life they had inherited from their ancestors. The rapid transformation of the historical Delta over 160 years involved many changes. Over 1,000 miles of levees were constructed to drain wetlands and protect islands from damaging floods. Channels were cut between sloughs or through islands to ease navigation and encourage drainage without regard to effects on the estuary. Forests were cut and land leveled for farming (Hanak et al. 2011). This transformation produced the rich agricultural economy and rural culture of the Delta described in Chapter 5. But it came at a cost: loss of the original estuarine ecosystem and its species, and native people.

Comparison of Historical (early 1800s) and Modern Delta Waterways

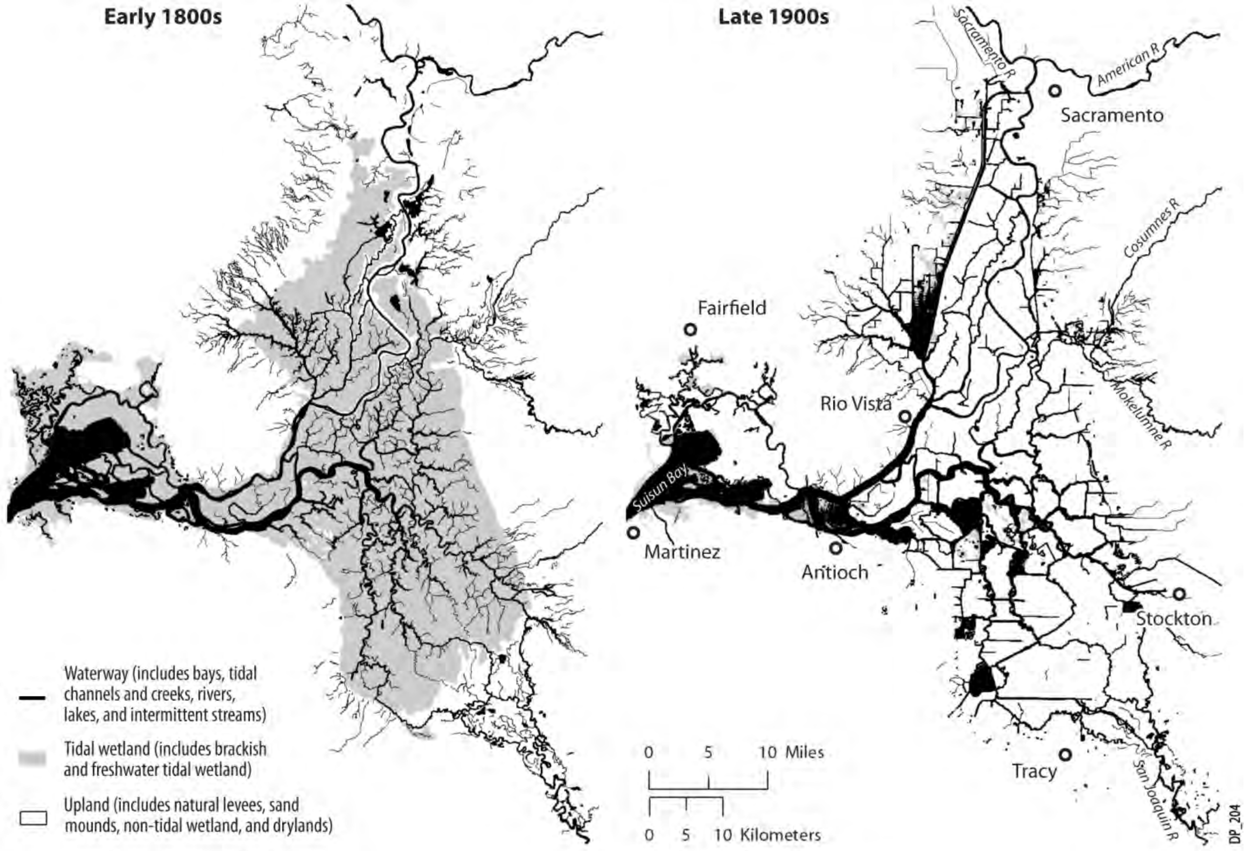
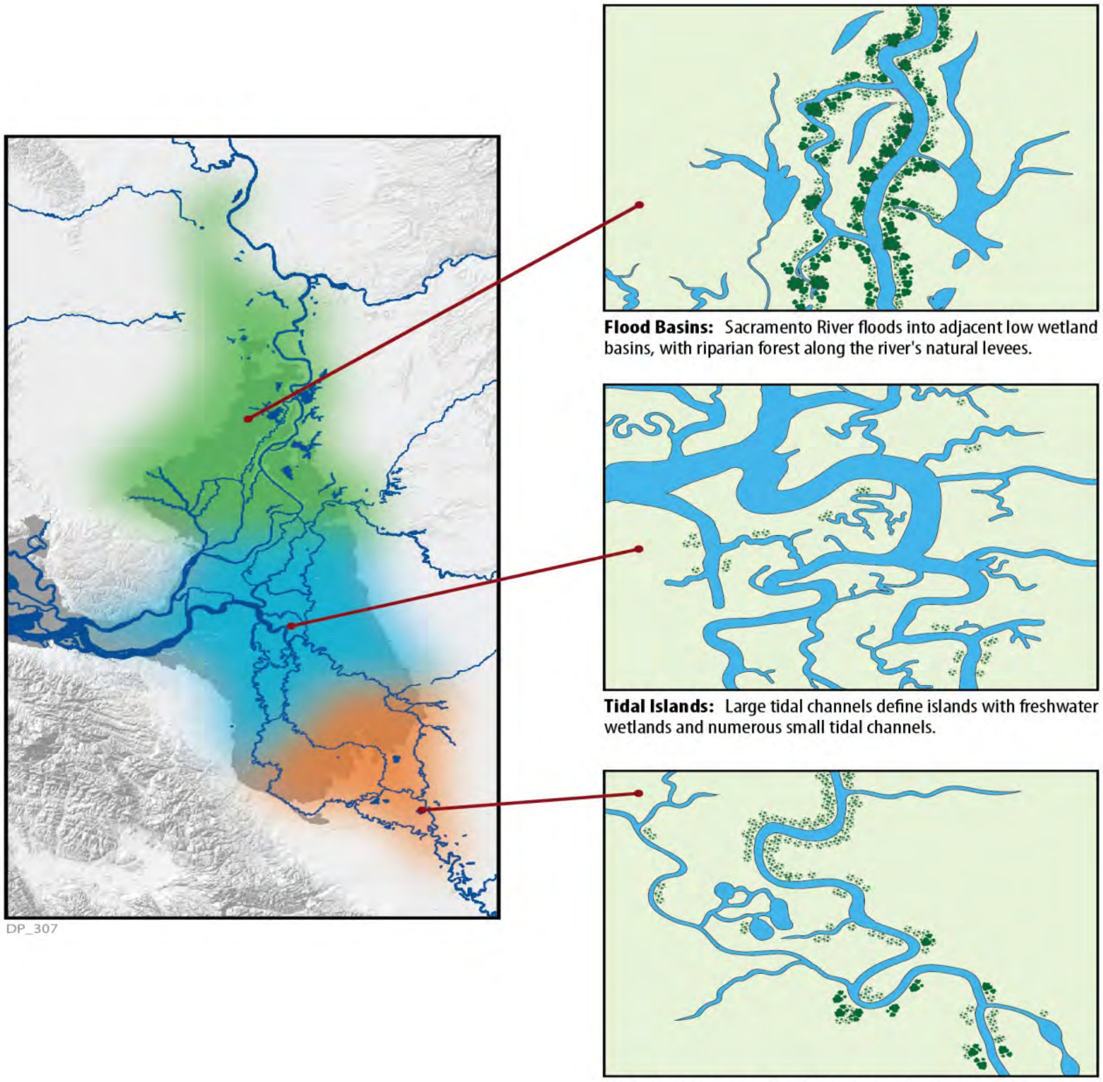


Figure 4-1 The map at left shows the complexity of early 1800s Delta hydrography (black) within tidal wetland (gray). The modern hydrography at right shows major differences such as channel widening, meander cuts, cross levees, and loss of within-island channel networks and tidal wetland.

Source: San Francisco Estuary Institute 2012

Primary Landscapes in the Historical Delta



Flood Basins: Sacramento River floods into adjacent low wetland basins, with riparian forest along the river's natural levees.

Tidal Islands: Large tidal channels define islands with freshwater wetlands and numerous small tidal channels.

Distributary Rivers: San Joaquin River branches merge into tidal wetlands within a floodplain with a wide mix of habitats.

Figure 4-2

The historical Delta can be divided into three primary landscapes: flood basins in the north Delta, tidal islands in the central Delta, and distributary rivers (rivers with multiple branches flowing away from main channels) in the south Delta. Transitions between these landscapes occurred gradually, across broad areas. Though these landscapes held many habitat types in common, characteristics and spatial patterns varied greatly—these large-scale patterns are what helped define the landscapes, which in turn provided different functions for native species. Understanding these major landscape types is a valuable framework for evaluating current and future restoration strategies in the Delta, providing a baseline between the current landscapes and the long-established historical patterns.

Source: Whipple 2011

Nearly all the rivers historically flowing to the Delta were dammed, creating Shasta, Folsom, Millerton, and Oroville lakes and other impoundments described in Chapter 3. These dams, together with levees constructed to prevent flooding, blocked access to spawning areas and other habitats critical to salmon, splittail, and other fish. The once pronounced seasonal and year-to-year variability of river flows has given way to more stable, artificially regulated conditions. The formerly complex Delta sloughs have been replaced by a simplified grid of straightened channels, cuts, and often rock-lined rivers fixed in space and time, and used for water conveyance and shipping. Pumps to divert water for irrigation or municipal use south or west of the Delta further disrupted the estuary (see Figure 4-3).

Ecosystem restoration cannot restore the historical Delta. Its alteration is too complete to reverse and could not occur without damage to other beneficial uses of its water and land. The Delta Reform Act recognizes these limitations and defines restoration as a "...close approximation of its natural potential..." (Water Code section 85066).

Ecosystem Stressors

Many factors stress the Delta's ecosystem (Baxter et al. 2010). Stressors are actions or factors, whether caused by humans or nature, that negatively affect the ecosystem processes and functions. Stressors include altered flows, habitat loss, entrainment in Delta diversions, degraded water quality, harmful nonnative species, migration barriers, and impacts from hatcheries. Reducing one stressor, or even several stressors, is unlikely to solve all environmental problems in the Delta (Delta ISB 2011, see Appendix I). Many restoration projects fail because multiple stressors have been insufficiently considered (Palmer et al. 2005). Because of uncertainty over cause and effect, ecosystem restoration must address as many stressors as possible through adaptive management, as described in Chapter 2 and Appendix C.

Organizing stressors into categories, such as those developed by the Delta Independent Science Board (ISB), helps resource managers to think about, assess, and manage them. (See sidebar, Stressor Categories to Help with Management Options.) Ecosystem stressors and their effects can be categorized by what causes them (sources of stress) or by what can be done about them. The Delta Plan's ecosystem restoration strategies address the following current stressors:

- Delta flows
- Habitat
- Ecosystem water quality
- Nonnative species
- Hatcheries and harvest management

STRESSOR CATEGORIES TO HELP WITH MANAGEMENT OPTIONS

The Delta ISB developed categories that put Delta stressors into broad context to help assess management options (for example, what can be done about them) (Delta ISB 2011). Management options are stressor reduction, elimination, or mitigation. When this is not possible, adaptation to stressors must be promoted. The Delta ISB has proposed the following categories:

- **Current stressors** result from ongoing human activities that at least in some cases can be eliminated (for example, fish entrainment at water diversions and pollution from point sources).
- **Legacy stressors** result from past actions that cannot be undone, but their impact can sometimes be reduced or mitigated (for example, mercury pollution from historical gold mining and past introductions of nonnative species).
- **Globally determined stressors** result from large-scale human activities or natural processes that cannot be eliminated or mitigated within the purview of the Delta Plan and require larger-scale planning and adaptation (for example, global climate change and human population growth).
- **Anticipated future stressors** require preparation (for example, future land subsidence, urban expansion, and new invasions by nonnative species).

These categories have some overlap; for example, a globally determined stressor such as sea level rise also can be an anticipated future stressor.

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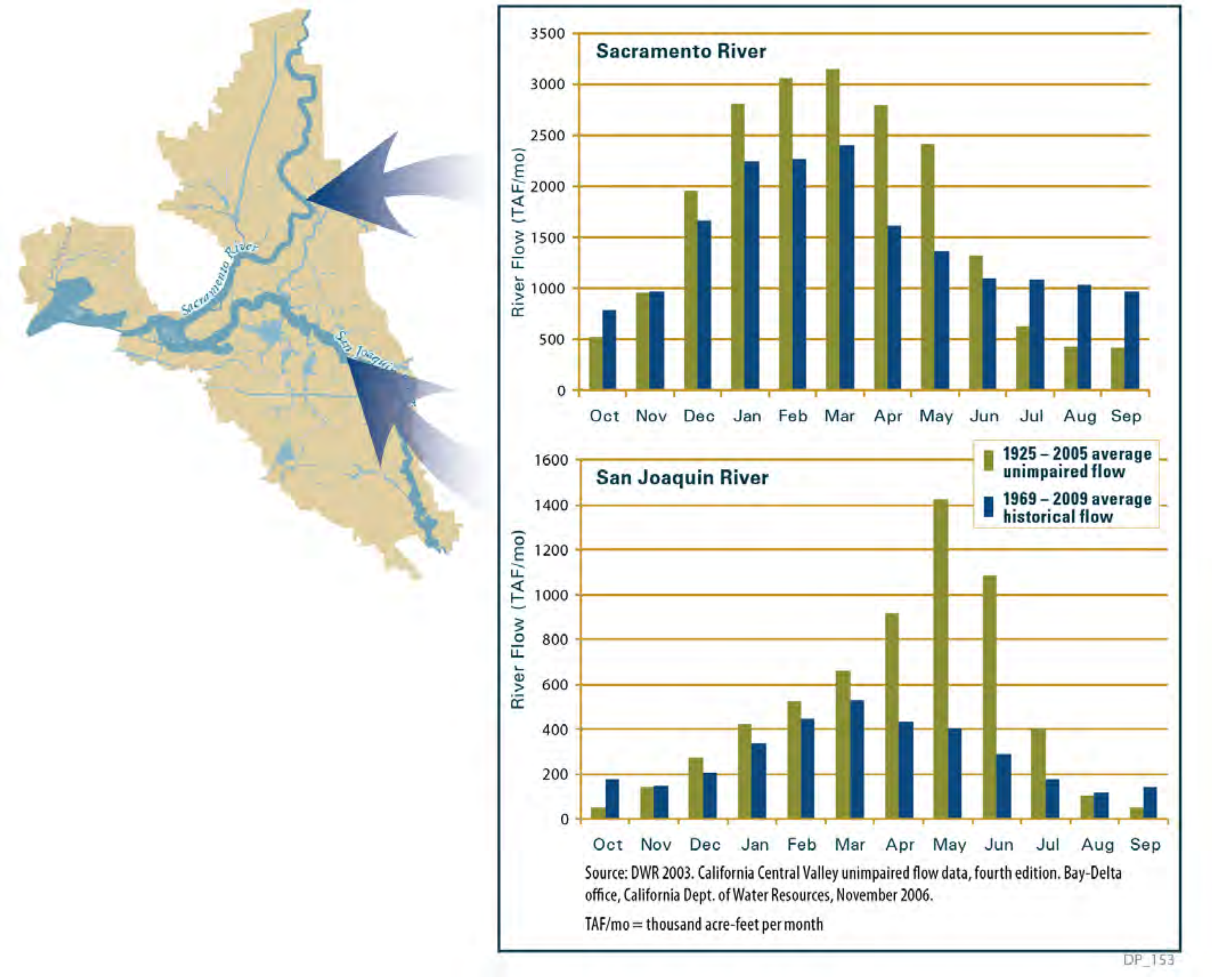
Changes in Historical Flows Challenge Delta Ecology



Source: DWR 2003. California Central Valley unimpaired flow data, fourth edition. Bay-Delta office, California Dept. of Water Resources, November 2006.

TAF/mo = thousand acre-feet per month

Figure 4-3

Habitat for native species has been shaped in the past by natural cycles of river flows.* Since the 1960s, our water system, with its upstream reservoirs, diversions, and other management facilities, has changed these patterns in two ways. First, seasonal flows are much less variable and encourage nonnative fish and vegetation, which can crowd out native species that thrive in a more varied environment. Second, peak flows now come at lower magnitudes and occur earlier on the San Joaquin; this shift affects water temperatures, salinity, and access to habitat, causing stress on native species.

** Natural flow is runoff that would have occurred had the landscape and waterways remained unaltered. Our best estimate of natural Delta inflow is "unimpaired flow," the flow that would be expected if reservoirs were removed but the contemporary watershed and valley land uses remained. However, natural and unimpaired Delta inflow are not the same, and the difference between them could be substantial at times.*

Climate Change

Climate change will cause major stresses on the Delta ecosystem. Rising sea level could inundate freshwater marshes and other freshwater aquatic habitats, potentially with brackish water, reducing habitat for native plants, fish, and wildlife. In addition to rising sea level, the amount of ideal low-salinity habitat for native fish such as the delta smelt will be affected by changes in runoff timing and intensity, which will also affect erosion and sedimentation patterns, again altering fish habitat. Increased water temperature will negatively affect smelt, salmon, and other coldwater-dependent fish, and will likely increase the range of invasive species (Healey et al. 2008, Villamanga and Murphy 2010). In terrestrial habitats, warming could create soil moisture deficits, change plant community composition, and even disrupt timing between pollinators and plants (California Natural Resource Agency 2009). Overall climate change will exacerbate current challenges to the protection and restoration of Delta ecosystems.

Ecosystem Restoration

Restoration of the Delta ecosystem does not mean a return to predevelopment conditions with only its native plants and animals. That is beyond human ability. Instead, restoration seeks to return areas to a close approximation of their natural potential, including re-establishing natural habitat and ecosystem functions, as feasible, within the context of the current configuration of the Delta, the current biological communities, and the permanent modifications to Delta land forms and hydrology. Successful ecosystem restoration rehabilitates key elements—the living and nonliving features such as soils, elevation, waterways, species, populations, and habitats—and the structure and processes that connect them. This section summarizes the principles of and considerations for ecosystem restoration in the Delta.

Much work has been done to develop ecological principles specific to the Delta. (See sidebar, Delta Ecological Principles.) Restoration projects that adhere to these principles are more likely to achieve their goals and objectives.

The Delta Reform Act's definition of restoration recognizes that the ecosystem will be dynamic, changing in response to restoration actions and future climate change (Healey et al. 2008, Delta ISB 2011). The desired future condition is an evolving ecosystem that supports communities of both native and nonnative species, and continues to provide value such as clean water, flood storage, or recreational fishing. A dynamic, restored Delta ecosystem can be a natural complement to the Delta as an "evolving place" described in Chapter 5.

To increase the likelihood of ecosystem restoration success, plans and actions must incorporate the principles of adaptive management (see Chapter 2 and Appendix C for a detailed discussion). This begins with a clear, practical vision of what will be achieved for the ecosystem, together with human need for water supply reliability and flood risk reduction. Additional examples are provided in the sidebar, Current Delta Ecosystem Restoration Efforts.

DELTA ECOLOGICAL PRINCIPLES

The following are ecological principles for the Delta adapted from those developed for the Delta Vision Blue Ribbon Task Force by former CALFED Lead Scientist Michael Healey (2007a, 2007b) and for the Bay Delta Conservation Plan (BDCP) Steering Committee by the BDCP Independent Science Advisors (2007).

Principle 1: Humans are part of the Delta ecosystem. Human activities over the past 160 years have produced a Delta ecosystem that is different from the historical ecosystem, and will remain so even as human-induced stressors are modified.

Management implications: Strategic management of human activities, and uses of the landscape and water in the Delta will be integral to the successful protection, restoration, and enhancement of the Delta ecosystem.

Principle 2: The Delta ecosystem is part of larger ecosystems. The Delta ecosystem affects and is affected by surrounding ecosystems. High year-to-year variability in precipitation and river flows are, in part, caused by climate patterns that span the entire Pacific Ocean. In addition, many animals that use the Delta do so for only part of their life cycles, spending other parts upstream in the rivers, in the ocean, or as far as away as South America and northern Canada.

Management implication: Management of the Delta cannot occur independently of structures and events upstream and in the ocean, in regional and state economies, or in the wider governance context.

Principle 3: The Delta ecosystem is a mosaic of smaller terrestrial and aquatic ecosystems. These ecosystems interact in important ways (for example, exchange of material, energy, and species). This landscape mosaic determines overall performance of the ecosystem. The size, shape, arrangement, and connections within the mosaic are critical to the way the Delta functions.

Management implication: Management plans and decisions need to be informed by a landscape perspective that recognizes interrelationships among patterns of land and water use, patch size, location and connectivity, and species success. The landscape perspective needs to be developed at several physical and temporal scales.

Principle 4: The Delta ecosystem is naturally dynamic. This includes disturbances and extreme events such as very wet and very dry years. Changes in one part of the Delta may have far-reaching effects in space and time.

Management implication: The Delta cannot be managed as a homogenous or static system.

Principle 5: Native Delta species are adapted to a naturally dynamic Delta ecosystem. The natural Delta is dynamic and variable, and the organisms living there are adapted to that variability.

Management implication: In order to successfully protect, restore, and enhance the Delta, management needs to include actions that mimic, to some extent, the historical natural variability.

Principle 6: Each native Delta species has particular tolerances for habitat variables such as temperature, dissolved oxygen, salinity, turbidity, and toxic substances. Species distributions may shift if conditions change and exceed these tolerances. Increase of air and water temperature by even 2 degrees may make the Delta uninhabitable for some local species and also make it potentially inhabitable for species from warmer regions.

Management implication: Loss of some species from the ecosystem may be inevitable. For local species, refugia may have to be located in cooler regions if extinction is to be prevented. Additional actions may be necessary to alleviate a potential increase in nonnative invasive species.

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CURRENT DELTA ECOSYSTEM RESTORATION EFFORTS

Several significant ecosystem restoration planning and implementation efforts are worth noting:

- The draft Ecosystem Restoration Program (ERP) Conservation Strategy was released by the California Department of Fish and Wildlife (DFW) in 2011 (DFG 2011) to update the CALFED ERP plans from 2000. DFW collaborates with its federal fish agency partners, the U.S. Fish and Wildlife Service and National Marine Fisheries Service, to implement the ERP, including providing grants for Delta and Suisun Marsh restoration research and implementation.
- DFW and the California Department of Water Resources (DWR) are continuing to implement and plan for ecosystem restoration projects begun under the CALFED Bay-Delta Program located in Suisun Marsh, at Dutch Slough, at Cache Slough, in the Yolo Bypass, and at the Cosumnes Preserve's North Delta project.
- The *Suisun Marsh Habitat Management, Preservation, and Restoration Plan* is a comprehensive approach to restoring 5,000 to 7,000 acres of tidal wetlands and maintaining managed wetlands and their functions consistent with the CALFED program, the Suisun Marsh Preservation Agreement, applicable species recovery plans, and other interagency goals.
- The Bay Delta Conservation Plan (BDCP) is an overarching approach to large-scale ecosystem restoration now in the planning process (see sidebar, Bay Delta Conservation Plan and Delta Ecosystem Restoration).
- Several Habitat Conservation Plans (HCP) and Natural Community Conservation Plans (NCCP) for parts of the Delta are in place or under development in the Delta. These plans' purpose is to minimize and mitigate the impact of authorized incidental take of the endangered or rare species and their habitats. Completed HCPs and NCCPs in the Delta include the San Joaquin HCP and East Contra Costa County HCP/NCCP. The BDCP, Yolo County HCP/NCCP, South Sacramento HCP, and Solano Multispecies HCP are under development.
- The State Water Resources Control Board (SWRCB) is updating its Bay-Delta Water Quality Control Plan (Bay-Delta Plan). The first phase focuses on objectives to protect water quality for south Delta agriculture and San Joaquin River flow objectives to protect fish and wildlife. The second phase focuses on other changes to its Bay-Delta Plan to protect fish and wildlife, including Delta outflow objectives, Sacramento River flow objectives, export/inflow objectives, Delta Cross Channel Gate closure objectives, Suisun Marsh objectives, potential new reverse flow objectives for Old and Middle rivers, potential new floodplain habitat flow objectives, potential changes to the monitoring and special studies program, other potential changes to the program of implementation, and issues identified through the BDCP process. As part of the SWRCB's review of its Bay-Delta Plan, it will consider information developed as part of its 2010 staff technical report *Development of Flow Criteria for the Sacramento–San Joaquin Delta Ecosystem* (SWRCB 2010) along with information about other factors, such as coldwater pool requirements and other water uses.
- In 2009, the Legislature established the Sacramento–San Joaquin Delta Conservancy (Delta Conservancy) as a primary State agency to implement ecosystem restoration in the Delta, along with supporting efforts that advance environmental protection and the economic well-being of Delta residents. The Delta Conservancy adopted a strategic plan to guide its planning and implementation efforts in March 2012.
- DWR's Delta Levees Special Flood Control Projects program provides funding to local agencies in the Delta for habitat projects linked to flood management improvements. Similarly, DWR's *2012 Central Valley Flood Protection Plan* proposes new or enhanced flood bypasses, levee setbacks, and fish passage improvements that provide both flood risk reduction and habitat. This effort is discussed in more detail in Chapter 7.

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Delta Flows

The Delta is the upstream portion of the San Francisco Estuary, where ecosystems dominated by the Central Valley's rivers transition to the more ocean-influenced ecosystem of the downstream portions of the estuary. Water flow is a "master variable," driving the ecological health of rivers and their ability to support valued environmental services (Poff et al. 1997, Postel and Richter 2003). In estuaries, the interaction of river flows and ocean tides produces a salinity gradient from fresh water to brackish and salty water. River flows and ocean tides also deposit and erode sediment to shape the estuarine landscape and its habitats. Estuarine species are adapted to the complex natural flow, salinity, and sediment dynamics in their native estuaries.

Delta flows can be divided into three categories: (1) river and floodplain flows, (2) in-Delta net channel flows, and (3) net Delta outflows (SWRCB 2010). Each category has different ecological effects. (See sidebar, Flow Is More than Just Volume.)

BAY DELTA CONSERVATION PLAN AND DELTA ECOSYSTEM RESTORATION

The parties seeking permits pursuant to the Bay Delta Conservation Plan (BDCP) are attempting to formulate a 50-year plan that, if successful, would ultimately contribute to the recovery of priority species, restoration of a more naturally functioning Delta ecosystem, and establishment of a secure and reliable water supply from the Delta for human use.

As discussed in the Chapter 3 sidebar, BDCP and Water Supply Reliability, the BDCP is a planning process intended to result in the issuance of permits from the California Department of Fish and Wildlife (DFW) under the Natural Community Conservation Planning Act and from the U.S. Fish and Wildlife Service and the National Marine Fisheries Service pursuant to Section 10 of the federal Endangered Species Act (ESA). In addition, the Bureau of Reclamation will use the information developed from this process to obtain incidental take authorization through an ESA Section 7 process. The BDCP proposes to contribute to the restoration of the health of the Delta's ecological systems by contributing to a more natural flow pattern than existing conditions within the Delta and by implementing a comprehensive restoration program.

As currently proposed, the BDCP takes an approach to supporting landscape-level processes by creating a reserve system consisting of a mosaic of natural communities that would be adaptable to changing conditions (including sea level rise) to sustain populations of covered species and maintain or increase native biodiversity (BDCP 2012). The proposal considers protection of at least 31,000 acres of existing natural communities, and restoration or creation of at least 72,809 acres of natural communities, including at least 65,000 acres of tidally influenced natural communities. In addition, the BDCP is intended to improve the Delta ecosystem by taking actions such as:

- Protecting and improving habitat linkages to promote the movement of native species
- Accommodating future sea level rise by providing transitional areas that allow future upslope establishment of tidal wetlands
- Allowing natural flooding to promote the regeneration of vegetation and related ecosystem processes
- Connecting rivers and their floodplains to recharge groundwater, provide fish spawning and rearing habitat, and increase food supply
- Managing the distribution and abundance of nonnative predators to reduce predation on native special-status species

Examples of elements of the BDCP strategy to support natural communities include:

- Controlling invasive nonnative plant species
- Restoring or creating 5,000 acres of riparian forest
- Restoring corridors of riparian vegetation along 20 miles of channel margin
- Restoring 2,000 acres of grassland
- Protecting at least 20,000 acres of cultivated land to support suitable habitat for native species

The BDCP also plans to propose comprehensive programs for monitoring, research, and adaptive management.

If the process is successful and DFW approves the BDCP as a natural community conservation plan pursuant to Chapter 10 (commencing with Section 2800) of Division 3 of the Fish and Game Code, and determines that the BDCP meets the requirements of this section, and the BDCP has been approved as a habitat conservation plan pursuant to the federal ESA (16 United States Code section 1531 et seq.), the Council shall incorporate the BDCP into the Delta Plan (Water Code section 85320(e)). The Council has a potential appellate role regarding the inclusion of the BDCP in the Delta Plan.

As of this publication, the final public draft of the BDCP and the related environmental impact report/environment impact statement are expected to be released in late 2013. The Council is a Responsible Agency for California Environmental Quality Act purposes.

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1. **River and floodplain flows.** The Sacramento and San Joaquin rivers and their tributaries provide fresh water into the Delta. Along the margins of the Delta, these rivers seasonally inundate floodplains. Inundated floodplains stimulate the food web by enhancing plant growth, triggering aquatic invertebrate production, exporting food that becomes available to animals downstream, and providing spawning and rearing habitat on the floodplain for fish such as salmon and splittail. In recent decades, floodplains like the Yolo Bypass are flooded primarily by very high flows that flood the Yolo Basin about one year in three. Floodplain restoration could re-establish topographic connections that flood the bypass more often and at lower flows.

2. **In-Delta net channel flows.** Delta flows are primarily driven by tides affected by the moon's cycles, river inflows, in-Delta agricultural diversions, and water exports through the Central Valley Project (CVP) and the State Water Project (SWP). Averaging these influences in any Delta channel over about 1 day gives the "net flow." Locations near the CVP and SWP export pumps, such as parts of Old River and Middle River in the south Delta, experience net "reverse" flows when export pumping by the water projects exceeds these channels' normal downstream flows. The average flow in these channels actually runs backward at times, which affects the Delta's aquatic ecosystems both directly and indirectly (see Figure 4-4). Reverse flow in the southern Delta is associated with increased entrainment of some fish species (Grimaldo et al. 2009) and disruption of migration cues for migratory fish (see the Migratory Corridors for Native Species section for more detail). Reverse and otherwise altered flows caused by upstream reservoir operations, the constraints of artificially connected Delta channels, plus water exports affect Delta habitat largely through effects on water residence time, water temperature, and the transport of sediment, nutrients, organic matter, and salinity (Monsen et al. 2007). These reverse flows could, in turn, affect the behavior of migrating fish, and habitat suitability for resident and migratory fish and other species. Finally, aquatic organisms often get drawn (entrained) into water pumping facilities, as described later in this chapter.

3. **Net Delta outflows.** Net Delta outflow is the sum of all inflows to, and diversions from, the Delta. It is the flow out of the Delta that would occur in the absence of tides (Oltmann 1988). During dry periods, outflow is a low percentage of the instantaneous tidal flow in the western Delta. Nevertheless, over periods longer than 2 weeks, Delta outflow transports river-derived organic matter to Suisun Bay (Jassby and Cloern 2000) and controls the location of the salinity gradient (Jassby et al. 1995). Delta outflow objectives are based on the monthly average location of the low-salinity zone in the western Delta. Outflow variability is recognized as a key factor promoting diverse native fish communities (Moyle and Mount 2007, Moyle et al. 2010).

FLOW IS MORE THAN JUST VOLUME

Flow is not simply the volume of water, but also the direction of flow, the timing of flow, the frequency of specific flow conditions, the duration of various flows, and the rate of change in flows.

Bunn and Arthington (2002) present four key principles underlying the links between hydrology and aquatic biodiversity and the impacts of altered flow regimes: (1) flow determines physical habitat, (2) aquatic species have evolved life history strategies based on natural flow regimes, (3) upstream-downstream and lateral connectivity are essential to organism viability, and (4) invasion and success of nonnative species is facilitated by flow alterations. Altered flow regimes have been shown to be a major source of degradation to aquatic ecosystems worldwide (Petts 2009).

DP-169

Flow Direction in South Delta

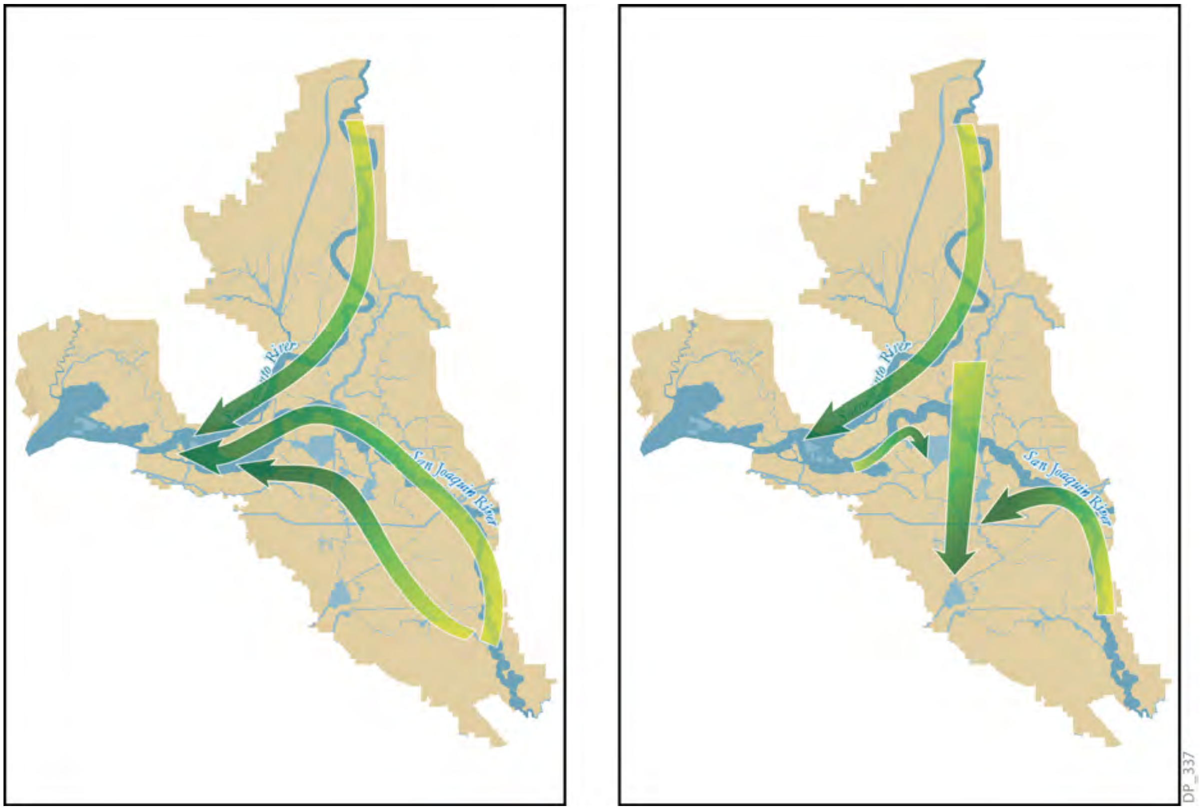
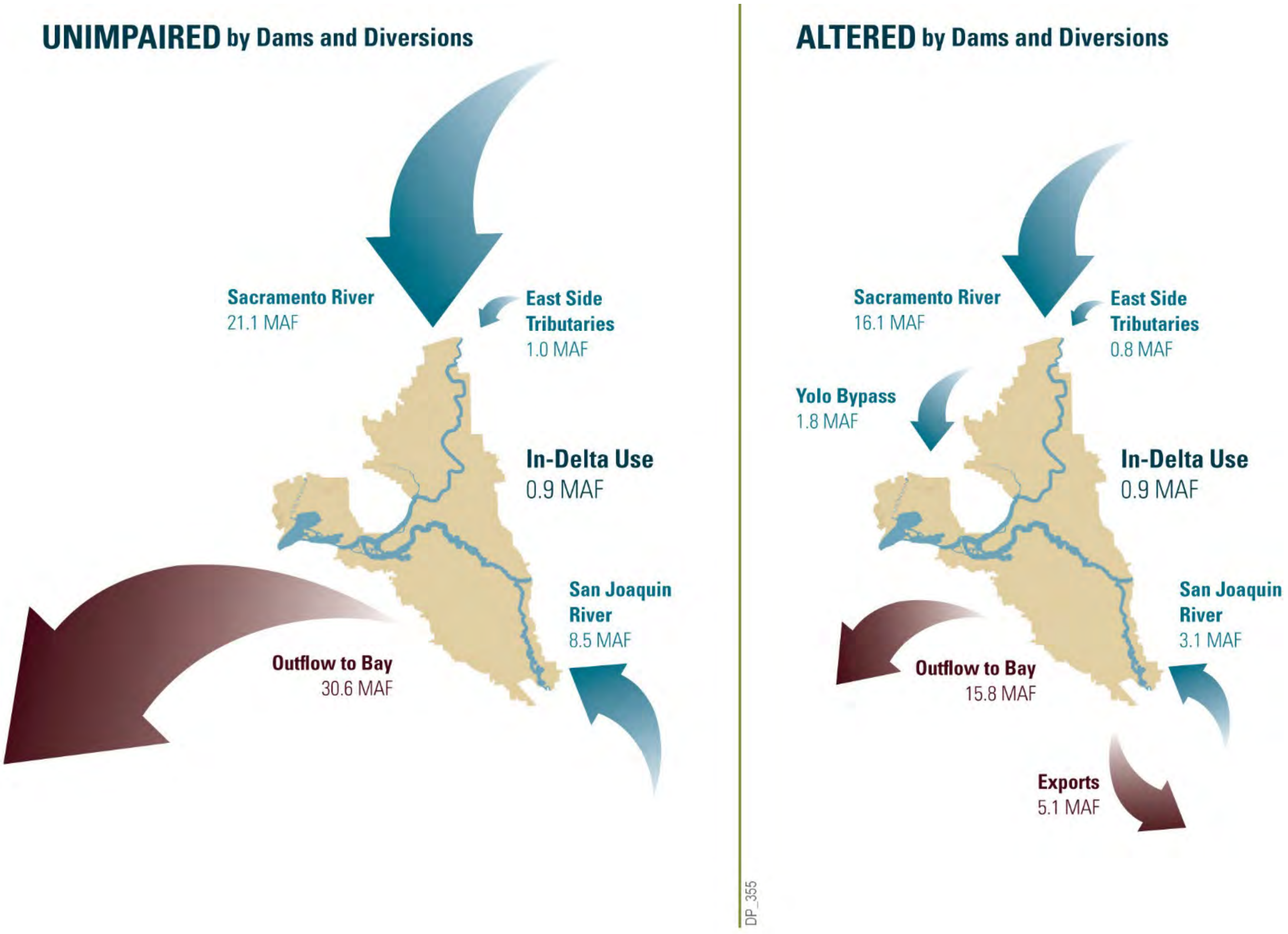


Figure 4-4 The left panel depicts the tidally averaged flow direction in the absence of export pumping. The right panel depicts reversal of tidally averaged flows that occurs during times of high exports (pumping) and low inflows to the Delta.

Present-day Delta flows are very different from historical, natural flows. Water flows have been altered by water supply and flood control infrastructure, including dams on the Sacramento and San Joaquin rivers and their tributaries; levees along these rivers and the Delta's channels; and draining of floodplains, wetlands, and groundwater basins (see Figure 4-5). Flows sometimes have not reflected the Fish and Game Code section 5937 requirement that dam owners should allow sufficient water at all times to pass through a fishway, or in the absence of a fishway, to pass over, around, or through the dam, to keep in good condition any fish that may have been planted or that exist below the dam (DFG 2012). Flows are now closely managed by releases from reservoirs to supply water for agricultural and urban uses, control salinity, and reduce floods. In the Delta, flows have also been rerouted through artificial channels. Flow management and modified Delta channel geometry have altered the salinity and sediment regimes in the Delta (Enright and Culberson 2010, Wright and Schoellhamer 2004), managing salinity for human uses rather than for fish and wildlife. Low winter-spring flows disrupt turbidity and salinity cues for migrating fish (Grimaldo et al. 2009), reduce access to spawning and rearing habits in tributaries and floodplains (Sommer et al. 1997, Feyrer 2004, Feyrer et al. 2007), and limit success for young fish trying to follow natural migration patterns (Feyrer and Healy 2003). Current flow management regulations provide some protection for ecological functions and native species, but the current Delta flow regime is generally harmful to many native aquatic species while encouraging nonnative aquatic species (SWRCB 2010).

Effects of Dams and Diversions on Delta Inflows and Outflows



Data presented as a long-term average. Information based on DWR CALSIM II modeling, which includes projected conditions to protect fisheries.

Delta-Suisun in-Delta use includes water to the Contra Costa Canal and to the Mokelumne and Hetch Hetchy aqueducts.

MAF = millions of acre-feet

Figure 4-5

Water flows more closely approximating the timing, frequency, duration, volume, and rate of change of flow produced naturally by a region's climate are best for native aquatic communities (Poff et al. 1997, Bunn and Arthington 2002, Carlisle et al. 2010). Flow is a major environmental input that shapes ecological processes, habitat, and biotic composition in riverine and estuarine ecosystems such as the Delta. Returning to a more naturally variable hydrograph is a key component of ecosystem restoration because the hydrograph works hand-in-hand with habitat restoration to produce diverse and interconnected food webs, refuge options, spawning habitat, and regional food supplies (Carlisle et al. 2010). Flows should provide species benefits and water supply reliability in the context of current hydrological conditions and degraded habitat. In some cases, flows to benefit the ecosystem will deviate from historical "natural" flows, because the channel geometry, land-water connectivity, and infrastructure limits our ability to mimic historical conditions. Flows will also need to be modified as habitat areas are restored. The Delta Plan, therefore, calls for "more natural functional flows" in the Delta as an important aspect of ecosystem restoration. (See sidebar, More Natural Functional Flow, for a description.)

Flow-related stressors can be reduced or mitigated through improved flow management and concurrent reduction of other stressors. Improved flow management comes from better use of current or improved water infrastructure. The challenge in managing flows is to both restore the Delta ecosystem and improve water supply reliability. Flow-related stressors are likely to increase as population grows and the climate changes. Preparation for these changes must start now.

The State Water Resource Control Board's (SWRCB's) Bay-Delta Water Quality Control Plan (Bay-Delta Plan) identifies water quality objectives to protect beneficial uses of the Bay and Delta, and an implementation program including control of salinity (caused by saltwater intrusion, municipal discharges, and agricultural drainage) through water projects operations. This is a contentious issue of public policy, and the Delta Reform Act directed the SWRCB to develop its new flow criteria using the best available science (Water Code section 85086).

The SWRCB is updating the 2006 Bay-Delta Plan with these steps: (1) review and update water quality objectives, including flow objectives, and the program of implementation in the 2006 Bay-Delta Plan, and (2) make any needed changes to water rights and water quality regulation consistent with the program of implementation. Updating the water quality objectives for the Delta, including an update of flow objectives, is important to protect the Delta ecosystem and the reliability of the Delta's water supplies. The sooner these objectives are set, the earlier the ecosystem can be protected and restored, the greater the possibility that a successful Bay Delta Conservation Plan (BDCP) will be approved, the earlier a more reliable water supply can be improved, and, therefore, the earlier the coequal goals can be achieved. That is why the Delta Plan calls upon the SWRCB to complete its work by specified deadlines. A more detailed explanation of the SWRCB's development of water quality objectives, including flow objectives, is included in Chapter 6.

Entrainment Is One Effect of Altered Flows

Entrainment occurs when fish and other aquatic life are drawn into a water diversion intake and are unable to escape. In the Delta, entrainment occurs primarily at the CVP facilities (Tracy Fish Facility and the nearby Delta-Mendota Canal) and the SWP facilities (including Clifton Court Forebay and the Skinner Fish Facility), as well as other smaller Delta intakes.

Much of the time, net channel flows in most of the south Delta are toward the pumps. This increases the probability that small, weak-swimming young smelt or salmon will be entrained. Depending on the type and size of the fish, the closer a fish is to the pumps, the more likely it is to be entrained. Greater reverse flows caused by pumping in the south Delta increase the numbers of fish entrained.

Some of the entrained fish are "salvaged," meaning they are caught in facilities at the pumps and then trucked and released to an area beyond the pumps' influence. The salvage process decreases the mortality of entrained fish (including salmon). Unfortunately, however, many fish, including delta smelt, are not able to survive the collection, handling, transport, and release.

MORE NATURAL FUNCTIONAL FLOW

What is natural Delta flow? Natural Delta flow is the historical (before 1849) pattern of watershed flows that eventually arrived in the Delta. Historical Delta flows resulted from rainfall in the watershed and the pattern of water storage and release from mountain snowpack, forest and valley soil and vegetation, and the natural topography of creeks, rivers, natural levees, and valley floodplains. These landscape patterns have been modified since 1849, and will largely not be returned to their former state.

Why is natural flow important? Native species are adapted (by natural selection) to the seasonal, interannual, and spatial variability of the historical flow pattern and the functions that come with it. Flows interact with land to create physical habitats and connections where species find food, refuge, and reproduction space. Through a variety of mechanisms, native species can survive, grow, and reproduce better when flows occur in more natural historical patterns.

What does natural flow look like? There were no measurements of natural Delta flow before the watershed was modified by gold mining, agriculture, and water storage. In general, natural flows rise in concert with precipitation patterns and fall slowly as the natural water storage capacity of the watershed is released. Natural flows are not simply water volumes but also include the seasonal timing, magnitude, frequency, duration, and rate-of-change in flows. It is often asserted that "unimpaired Delta inflow" is a good approximation of natural flow. For the Delta, unimpaired flow is the inflow that would be expected if reservoirs were removed but contemporary watershed and valley land uses remained. Unimpaired Delta inflow may overestimate the magnitude of natural Delta inflow and abridge the timing of seasonal peaks.

Will more natural flow work to meet ecosystem goals? Not by itself. Natural flows exist only in the context of natural landscape patterns. The pattern of historical natural flow reflected seasonal and interannual interaction with the historical landscape. For example, historical high flows in winter and spring were intercepted and stored by natural floodplains and then released slowly to the Delta through the summer. Much of the ecosystem functional value of natural flows occurs in these seasonal land and water interactions.

We do not have natural landscapes, so now what? Until large-scale restoration is in place, we can meet ecosystem goals in the interim by using the best available scientific understanding of the *functions* that flows provide to native species. For example, winter-run salmon historically survived low summer flows by finding cold-spring creeks in the watershed for spawning. These creeks are now blocked by dams, but cold water can be released from reservoirs to improve spawning habitat farther down. Another example is using Delta outflow to position the low salinity zone ("X2") in Suisun Bay at key times of the year when the salinity, refuge, and food resources there can benefit native fish. More natural flow is therefore understood to emphasize more natural *functions* rather than the shape of the hydrograph. More natural functional flows could include diverting more flow in wet years and less flow in dry years, as described in Chapter 3. With landscape restoration over time, managing water for functional natural flows should be adaptively managed as ecosystem conditions change. The Delta Plan call for "more natural functional flow" suggests that we can adaptively manage the *functions* that flows provide to the life history needs of native species. Therefore, managing for more natural functional flows protects, restores, and enhances the Delta ecosystem.

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Alteration of water flows also leads to losses of fish from predation. High rates of predation occur at the pumps, and the sloughs and channels near the pumps. Small fish drawn into this part of the Delta have a very low chance of survival. Juvenile salmon drawn into the central Delta through the Delta Cross Channel or Georgiana Slough also have a lower chance of survival than fish staying in the Sacramento River's mainstem. Whether the effects of flow on fish are direct through entrainment or indirect through increased mortality caused by altered flows and predation, the results are the same: fish lost as a result of Delta diversions.

Because of all these factors, managing flows within the Delta is a difficult but important tool for protecting fish. For example, the SWRCB requires reductions in diversions and increases in San Joaquin River inflows during springtime to increase the survival of outmigrating juvenile salmon. The biological opinions for salmon and smelt include measures to reduce entrainment and indirect loss of fish due to altered flows caused by the SWP and CVP diversions. These actions include restrictions on reverse flows in the Old River and Middle River channels in the south Delta and requirements for closing the Delta Cross Channel gates.

Entrainment does not just occur at the Delta pumps. It also can occur at other diversions upstream from the Delta. Larger diversions upstream and in the Delta are screened, but many smaller diversions are not. In-Delta unscreened diversions do not currently appear to entrain substantial numbers of salmon or smelt.

Habitat

Appropriate habitat is required for any organism to survive and reproduce (Hall et al. 1997). Because no two species have exactly the same requirements, habitats are species-specific components of ecosystems.

Expanding habitats for native species is an essential part of restoring the Delta's ecosystem. Recent biological opinions controlling long-term operations of the CVP and SWP require restoration of at least 8,000 acres of intertidal and associated subtidal habitats in the Delta, including Suisun Marsh (USFWS 2008). They also require restoration of 17,000 to 20,000 acres of floodplain rearing habitat for salmon in the Yolo Bypass and lower Sacramento River, including side channels and re-created floodplain terrace areas (NMFS 2009). Some of the tidal marsh acreage may also fulfill requirements for restored floodplains, depending on its location.

Habitat restoration, like water flow, is not just about quantity (or extent), but also about quality, connectivity, and diversity. Land cover types, such as open-water and riparian vegetation, vary greatly and are only one element of habitat (Lindenmayer et al. 2008); an organism's habitat is much more than just land cover. For example, the area of the Delta covered by open water has not changed substantially during the last few decades, but several open-water fish have declined steeply (Sommer et al. 2007, Baxter et al. 2010). This suggests that some of the Delta's open waters have become inhospitable to these certain fish species. The functional habitat available to these open-water fish has shrunk even though the area covered by open water has remained fairly stable. This means that simply changing land cover (for example, increasing riparian habitat) does not automatically increase target species. Other stressors such as poor water quality, predation, or entrainment may make these areas unsuitable.

Habitat loss and fragmentation resulting from human land use causes species loss worldwide (Foley et al. 2005). In estuaries and coastal areas, habitat destruction, coupled with exploitation such as overfishing, are the leading causes of species declines and extinctions (Lotze et al. 2006). Habitat restoration can help recover native species, particularly when other stressors such as altered flows, degraded water quality, or predation by introduced species are also reduced (Carlisle et al. 2010, Lotze et al. 2006).

Taking a large view of an ecosystem, habitats are species-specific "patches" in spatially varied landscapes. The survival and success of organisms is closely associated with the total amount of usable habitat, as well as with habitat patch sizes, shapes, and arrangements (Hannon and Schmiegelow 2002). Habitats that are too small, fragmented, or isolated may not provide long-term support for specific organisms. In general, more, larger, and better-connected patches of a specific habitat create the conditions for persistence or recovery of the species associated with that habitat (Lindenmayer et al. 2008). (See sidebar, Landscape Ecology: A Fundamental Tool for Restoration Planning.)

Much of the original habitat for the Delta's native fish, wildlife, and plants has been urbanized or converted to agriculture over the past 160 years (Healey et al. 2008, Moyle et al. 2010, Baxter et al. 2010). This habitat loss is one of the largest legacy stressors to the Delta ecosystem. The current Delta ecosystem continues to be productive, but its habitat types and conditions support a much different mix of species than the historical Delta. Many of the thriving species are nonnative, such as largemouth bass and the Brazilian water weed *Egeria densa*. Some consider a few nonnative species, such as bass prized by anglers, to be desirable. But too many nonnative plants and animals can upset an ecosystem's balance, creating conditions unsuitable for native aquatic and terrestrial species (Sommer et al. 2007, Healey et al. 2008, Baxter et al. 2010). This conflict and the inadequate habitat for native species that reside in and migrate through the Delta is an important current ecosystem stressor that must be addressed.

LANDSCAPE ECOLOGY: A FUNDAMENTAL TOOL FOR RESTORATION PLANNING

Landscape ecology examines the influence of spatial patterns on ecological processes (Wiens 2002) and considers the ways that species use the landscape for finding food and refuge, and for adapting to change (Simenstad et al. 2000, Lindenmayer et al. 2008). The mosaic of landscape features—or "patches"—and the connections between patches affect species' locations, food and cover, the energy required to obtain those resources, and, ultimately, survival. The landscape perspective considers connections and exchanges between uplands; riversides and wetland edges; and the sloughs, channels, and bays that make up estuarine aquatic habitats. The food webs of these adjacent systems exchange organisms and energy that, in turn, can increase the productivity of each (Cloern 2007). Native estuarine species—terrestrial, semiaquatic, and aquatic—are adapted to the rhythms of the landscape's mosaic of connected habitats and its dynamic processes.

From a landscape perspective, "form begets function." Therefore, correct spatial structure and patterns are prerequisites for restoring and maintaining desired ecosystem processes and functions, and for providing appropriate habitat for native species. In the long term, restoring spatial patterns at ecologically appropriate scales can promote the "self-repair" of ecosystem processes and functions (Teal et al. 2009) and increase resilience to stressors. Consequently, this approach could reduce the operating and maintenance costs of restoration in an era of limited resources. Planning for ecosystem restoration should always consider appropriately large spatial scales (regional or larger), but restoration actions can proceed at smaller scales to optimize the benefits that can be achieved with the often limited opportunities and resources available for restoration (Hermoso et al. 2012).

Additionally, landscape ecology considers people's role in shaping landscape patterns and processes (Turner 1989). Restored landscapes often have agricultural and urban neighbors. Each land use affects the other because they are connected by air, land, and water. Yet humans often want conflicting things (nature areas nearby with abundant wildlife, but also with convenient recreation facilities, no mosquitoes, and no impacts on adjoining farms). A functioning ecosystem depends on many things, including understanding and dealing with its relationship to human activities. The current regulatory and political framework for restoration projects often puts short-term benefits, such as low acquisition cost or immediacy of land availability, before long-term benefits of connectivity and appropriateness of scale. Landscape ecology provides a set of tools for assessing and prioritizing limited restoration opportunities. For example, using the principles of landscape ecology, decisions about land acquisitions for restoration must address how small parcels that become available for restoration might be connected and combined to maximize ecological benefits over the long term.

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The Importance of Land Elevation in Habitat Restoration

Opportunities for habitat restoration in the Delta are constrained first and foremost by the elevation of land, which determines the potential of an area to be restored. As described in Chapter 5, much of the Delta has subsided too deeply to restore its original ecological functions (see Figure 4-6).

Deeply subsided Delta lands can provide terrestrial and wetland habitat for native species only at great cost and with intensive management. They offer few opportunities to recover native ecosystem forms and functions. However, deeply subsided islands could include seasonal wetlands for waterfowl and wildlife-friendly agriculture. Actions that promote carbon sequestration, subsidence reversal, and improved migratory bird habitat are especially valuable.

The most promising restoration opportunities are found in the less-subsided flood basins, river corridors, and brackish tidal marshes on the Delta's perimeter, leading the Council to recommended six priority habitat restoration areas:

- **Yolo Bypass, from the Fremont Weir south toward the Delta.** Winter and spring flooding of the Yolo Bypass provides substantial benefits for spawning and rearing of Sacramento splittail and rearing of salmon (Sommer et al. 2001, Moyle et al. 2007). Projects in the planning stage include fish passage improvements and various approaches, such as notching the Fremont Weir to increase the frequency and duration of inundation during times of the year critical for spawning and rearing of native fish. Restoration of the Yolo Bypass can create conditions that promote enhanced growth and survival of juvenile spring- and winter-run salmon, among other species, and can benefit other migrating salmon.

Habitat Types Based on Elevation, Shown with Developed Areas in the Delta and Suisun Marsh

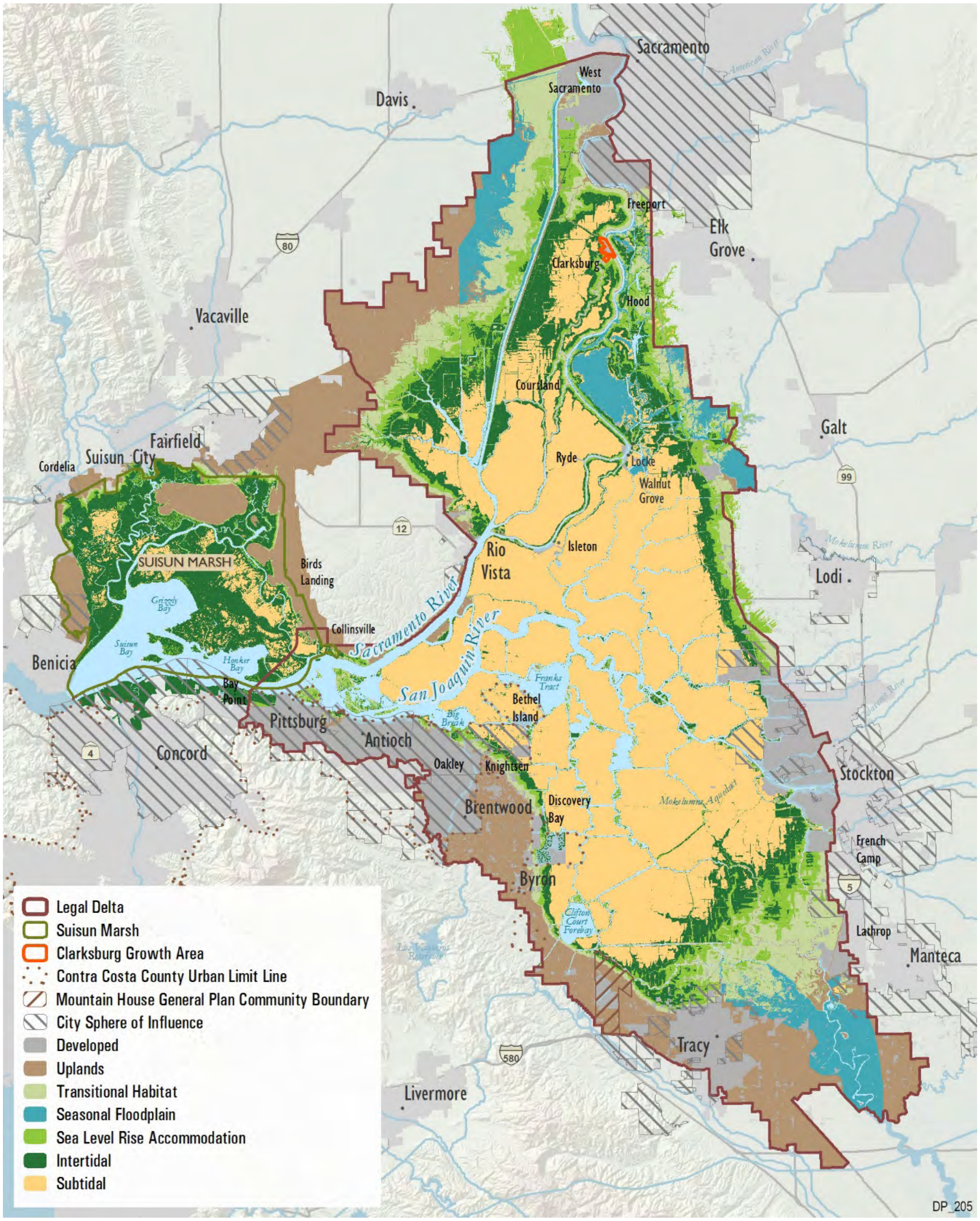

Figure 4-6

Source: Adapted from DFG 2011

- **Cache Slough Complex, southwest of the Yolo Bypass.** The flood basins entering the Cache Slough Complex are at the interface between river and tidally influenced portions of the Delta. A restoration project in this area is Liberty Island, which is being allowed to passively restore to marsh after floods breached the island's levees in 1997. Projects in the planning stage include California Department of Water Resource's (DWR's) Prospect Island restoration project. Habitat restoration at Cache Slough can create conditions that help recover delta smelt and that benefit migrating salmon. See the sidebar, Applying Adaptive Management to Ecosystem Restoration, for a hypothetical example implementing principles of adaptive management in projects such as these.
- **Cosumnes River–Mokelumne River confluence.** An existing restoration project is the Cosumnes River Preserve floodplain. Projects in the planning stage include DWR's North Delta Flood Control and Ecosystem Restoration Project on McCormack-Williamson Tract. Restoration here can benefit migrating salmon and contribute to the Delta's food webs.
- **Lower San Joaquin River floodplain between Stockton and Manteca.** Historically, the south Delta and its connection to the lower San Joaquin River contained a complex network of channels with low natural berms, large woody debris, willows, and other shrubs with upland areas supporting open oak woodlands. Projects in the planning stage include the Lower San Joaquin Flood Bypass proposed by the South Delta Levee Protection and Channel Maintenance Authority and its partners. Restoration to a mix of tidal marsh, riparian habitats, and wildlife-friendly agriculture could create conditions to recover riparian brush rabbits and Swainson's hawks, benefit migrating salmon, and serve to reduce the risks from flooding for urban areas.
- **Suisun Marsh.** This is the largest wetland area on the West Coast of the contiguous United States. Suisun Marsh is mostly managed for waterfowl, with levees that disconnect its wetlands from the estuary. An ongoing restoration project is DWR's Blacklock Restoration Project. Projects in the planning stage include California Department of Fish and Wildlife's (DFW's) Hill Slough Restoration Project. Restoration of tidal marsh and associated habitats here can create conditions that contribute to food webs in Suisun and Honker bays, and aid the recovery of longfin smelt and spring- and winter-run salmon.

  Unique local benefited species would also include Suisun song sparrows, saltmarsh harvest mice, and plants such as soft bird's-beak and Suisun thistle. Enhanced management of wetlands can reduce impacts on water quality while still maintaining or improving habitat for waterfowl of other wildlife.
- **Western Delta/Eastern Contra Costa County.** Some islands and tracts at appropriate elevations may be desirable sites for restoration of tidal marsh and channel margins to support food webs and provide habitat for native species. Decker Island is a recent restoration project in this area, and restoration at Dutch Slough is planned. Additional restoration of other islands or tracts may be considered in the BDCP or in local Natural Community Conservation Plans/Habitat Conservation Plans.

These six regions have been highly altered by more than a century of human use and exposure to multiple stressors. Returning a portion of these altered regions to habitat for native species requires a careful assessment of opportunities and challenges. Recommendations provided later in this chapter include actions to prevent or mitigate adverse impacts on opportunities for habitat restoration in these priority restoration areas.

Applying Adaptive Management To Ecosystem Restoration

An adaptive management approach to ecosystem restoration should be used to plan for and assess the ecological outcomes of the restoration action. The following is a hypothetical example of how the Council's three-phase and nine-step adaptive management frame-work (see Appendix C) could be applied to an ecosystem restoration project in the Cache Slough Complex.

Adaptive Management Step			Hypothetical Cache Slough Ecosystem Restoration Project
Plan	1	Define/redefine the problem	The Cache Slough Complex includes high biodiversity; however, ecological processes and habitat that benefit native species in the Cache Slough Complex are degraded.
	2	Establish goals, objectives, and performance measures	**Goal:** Re-establish natural ecological processes and habitats to benefit native species in the Cache Slough Complex. **Objective:** Re-establish the hydrologic, geomorphic, and ecological processes necessary for the long-term sustainability of native habitats, and the plant and animal communities that depend upon them. Improve floodplain connectivity and aquatic habitat quality for native estuarine species, including delta smelt, longfin smelt, Sacramento splittail, and Chinook salmon, by offering a suite of natural habitats and improving the food web fish require.
	3	Model linkages between objectives and proposed action(s)	The Cache Slough Complex provides high potential for restoration success because of its physical and biological attributes (such as tidal range, elevation, high amounts of suspended sediment, abundant zooplankton, and observed use by delta smelt). It is hypothesized that improved vernal pool and grassland habitats along with broad nontidal, freshwater, emergent-plant-dominated wetlands that grade into tidal freshwater wetland, shallow subtidal, and deep open-water habitat will increase the amount and quality of food for native species in the estuary. It is hypothesized that restoring tidal channel, wetland, and upland networks will improve conditions for native fishes. It is hypothesized that increases in the quality and quantity of food for native species will lead to increases in native species populations in the estuary. Native species expected to benefit from this restoration include delta smelt, juvenile Chinook salmon, Sacramento splittail, and longfin smelt.
	4	Select action(s) (research, pilot, or full-scale) and develop performance measures	Pilot-scale restoration project in the Cache Slough Complex: restore a subset of the processes supporting the creation of tidal channel, wetland, and upland networks to support native fishes. Performance measures: ▪ Administrative – Properties are identified for the pilot study. Funding sources and budgets for the project and monitoring are in place. Properties are acquired. Restoration planning and design is completed. Environmental compliance permits are obtained. Restoration contractors are selected. ▪ Output – Pilot-scale Delta habitat restoration project is implemented. Progress toward restoring diverse and interconnected habitats for native resident and migratory species in the Cache Slough Complex. ▪ Outcome – Progress toward achieving viable populations of native resident and migratory species. Trends in native Delta species are upward over the next decade.
Do	5	Design and implement action(s)	Design and implement the pilot-study restoration project.
	6	Design and implement monitoring plan	Design and implement the monitoring plan, including baseline monitoring of food abundance for pelagic organisms. Monitor the extent and quality of targeted habitats, connectivity of habitats, and abundance and diversity of species.
Evaluate and Respond	7	Analyze, synthesize, and evaluate	Analyze, synthesize, and evaluate the status and trends of changes in habitats, connectivity of habitats, abundance, and species health and diversity.
	8	Communicate current understanding	Provide project manager(s) and decision makers with annual reports of synthesized information learned. For example, provide a score card of the status and trends of species abundance and diversity, habitat connectivity, and so on.
	9	Adapt	The managers and implementers of the restoration project reconsider their understanding of the problem statement and conceptual model, and decide whether or not to expand from a pilot-study project to a larger-scale restoration effort.

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Migratory Corridors for Native Species

Habitat restoration often targets resident species that use the restored habitat year-round. Successful restoration, however, must also consider species that only periodically use particular habitat patches and corridors. The historical Delta provided migration corridors and rearing habitat for many migratory bird and fish species, including the threatened greater sandhill crane, many species of ducks and geese, salmon, sturgeon, and the introduced striped bass.

In the past, the Delta was a migration route and also an important nursery area for young salmon (or "smolts"). Much of the Delta today presents real risks to migrating salmon; it is no longer a suitable nursery for salmon smolts (Williams 2006). Some Delta channels do provide a greater chance of fish survival than others. For example, salmon leaving the Sacramento River and entering the interior Delta through the Delta Cross Channel have significantly lower survival than fish that stay in the river (Newman 2008), demonstrating that the central Delta has become a gauntlet of risk instead of a viable migratory corridor.

Entrainment at the CVP and SWP southern Delta pumps and increased predation kill salmon smolts. Toxic contaminants and periods of low dissolved oxygen can be harmful. Important factors for route selection and survival of salmon smolts on their way to the ocean include differences in flows through different channels, feeding opportunities, growth rates, and vulnerability to predation (Perry et al. 2009).

On their way back from the ocean to spawn, adult salmon must navigate a maze of Delta waterways where water from many different sources is mixed in artificially connected channels, and where rivers sometimes flow backward (reverse net flows in Old and Middle rivers; see the Delta Flows section) (Monsen et al. 2007). A unique problem is presented by the San Joaquin River, whose polluted and reduced flows are often drawn to the SWP and CVP pumps as a result of reverse flows. During these times, almost no water from the San Joaquin River reaches the confluence with the Sacramento River. Instead, water from the Sacramento River and its tributaries fills most of the Delta, obscuring and confusing the chemical and flow cues that salmon and other migratory fish depend on to find their destinations.

In addition to altered water flow and chemical disruption, migratory fish encounter dams, reservoirs, and other physical barriers that hinder their historical migration. The most formidable barriers are upstream on the Sacramento and San Joaquin rivers and their tributaries, especially the many large and small dams associated with reservoirs, including Shasta, Folsom, and Millerton lakes and Lake Oroville. In the Central Valley, less than one-fifth of the historical spawning habitat is still accessible to Chinook salmon and steelhead (Reynolds et al. 1993, Yoshiyama et al. 1996).

Physical barriers in the Delta help maintain water supplies for agriculture but interrupt fish migration; structures with ledges and drops, such as bridge pilings, boat docks, narrow channels with riprapped edges, or the intakes of the SWP and CVP pumps, create attractive spots for predatory fish to feed on migrating species. The Delta Cross Channel is an example. Sometimes, a barrier can have positive effects. Federal, State, and local officials have recently tested novel bio-acoustic fish fences (BAFFs) at Old River and Georgiana Slough that use light, sound, and air bubbles to steer migrating fish into channels that are thought to provide better habitat and a greater chance of survival.

Some high-quality migratory fish rearing and migration habitat remains at the margins of the Delta, if not in its core. The Yolo Bypass and Cosumnes River floodplains provide good migratory and rearing habitat for salmon, and important habitat for other native fish, birds, and bats. DFW manages the Vic Fazio Yolo Wildlife Area, a 16,000-acre public-private restoration project in the Yolo Bypass, to promote waterfowl and other bird populations. The 46,000-acre Cosumnes River Preserve is jointly owned and operated by The Nature Conservancy, Ducks Unlimited, the Bureau of Land

Management, DFW, DWR, Sacramento County, and private owners to create, enhance, and protect a variety of habitats. These are good illustrations of ecosystem and flood risk reduction projects working together. Wildlife-friendly agriculture also occurs in these floodplain preserve areas and their surroundings. During winter and early spring floods, these floodplains provide plentiful food for migrating salmon and native fish such as splittail, prickly sculpin, and Sacramento sucker (Sommer et al. 2001, Crain et al. 2004). Salmon migrating through these floodplains grow faster and have greater survival. (See sidebar, Better Habitat Equals Greater Growth.) Native fish do particularly well when flows through these floodplains follow more natural patterns. Early February through April, strong flood flows with cool water temperatures benefit many young native fish. Nonnative fish benefit more from later and lower flows with higher temperatures. Floodplain restoration should thus focus on early flooding followed by careful draining. This provides important migration and nursery habitat for native species while keeping nonnative species, including predators, at bay.

BETTER HABITAT EQUALS GREATER GROWTH

This comparison illustrates faster growth in floodplain habitat compared to river habitat. Salmon on the left were reared within Cosumnes River channel habitat, and the salmon on the right were reared within Cosumnes River floodplain habitat. All salmon shown are the same age.

Source: Jeffres et al. 2008

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Actions above and below the Delta also complement actions in the Delta to restore migratory corridors for fish and wildlife. The Bureau of Reclamation, U.S. Fish and Wildlife Service, and DFW have modified Shasta Dam to release colder water for salmon and trout, removed barriers to fish migration such as the Red Bluff Diversion Dam, screened water diversions to reduce entrainment, restored riparian habitats at the Sacramento River National Wildlife Refuge (NWR) and San Joaquin River NWR, and improved habitats in Sacramento and San Joaquin river tributaries where salmon spawn. Efforts to restore flows in the San Joaquin River also can rebuild these migratory corridors.

For example, on Battle Creek, actions to remove multiple dams and fish ladders are being implemented through the Battle Creek Salmon and Steelhead Restoration Project. The primary objective of the restoration project is to restore the ecological processes that would allow the recovery of steelhead and Chinook salmon populations in Battle Creek while minimizing the loss of clean and renewable hydroelectric power through modifications to the hydroelectric project. This project is among the largest coldwater anadromous fish restoration efforts in North America and will restore approximately 42 miles of habitat in Battle Creek and an additional 6 miles of habitat in its tributaries. It will also help restore critically imperiled winter- and spring-run Chinook salmon and Central Valley steelhead. Additional restoration actions are planned for other Sacramento River tributaries including Clear Creek, Deer Creek, and Mill Creek.

On the mainstem of the San Joaquin River between Friant Dam and its confluence with the Merced River, the San Joaquin Settlement Agreement will increase flows, expand channel capacity, and remove barriers to migration to restore spring-run Chinook salmon runs. This long-term action is expected to occur in stages over 20 years. On the Tuolumne River, the largest tributary of the San Joaquin River, the Central Valley Project Improvement Act (CVPIA)

Restoration Plan actions focus on restoring spawning, rearing, and floodplain habitat. The Bobcat Flat Restoration Project includes excavation of 48,500 cubic yards of gravel and coarse material that will be used to restore 1.6 miles of fall-run Chinook salmon and Central Valley steelhead spawning and rearing habitat. Similar habitat restoration projects have been implemented or are planned on other tributaries of the San Joaquin River and the Delta, including the Merced, Stanislaus, Calaveras, and Mokelumne rivers. However, 16 years after the creation of the CVPIA restoration fund, a panel of independent scientists issued a report on the CVPIA Fisheries Program (Reclamation and USFWS 2008) concluding that more could be done to effectively address the most serious impediments to survival and recovery of salmonids.

Wetlands bordering San Pablo Bay downstream of the Delta are home to a host of native and nonnative fish, waterfowl, shorebirds, other wildlife, and endangered plants and important stopping points on the Pacific Flyway. Uncommon species found in and around San Pablo Bay wetlands include longfin smelt, delta smelt, salt marsh harvest mouse, California clapper rail, San Pablo song sparrow, and black rail. All Central Valley anadromous fish migrate through the bay and depend on its open water and marshes for some critical part of their life cycle. The bay and its adjacent marshes are also important nursery grounds for many marine, estuarine, and anadromous fish. More than 40,000 acres of diked baylands and wetlands bordering the San Pablo Bay have been protected and are being restored.

In the Sacramento and San Joaquin valleys, actions to protect, restore, and enhance wetlands carried out by the Central Valley Joint Venture have significantly increased wildlife habitat resources for migratory waterfowl, shorebirds, waterbirds, and riparian songbirds in accordance with conservation actions identified in the Joint Venture's Implementation Plan. The Joint Venture establishes population objectives for these migratory birds then determines the appropriate amount of food, habitat, and water supply necessary to meet the objectives. Wetland restoration becomes a priority when habitat and forage needs for population objectives are not being met.

Successful recovery of native species requires effective habitat restoration. In addition to restoring physical habitat and corridors for movement, reducing other stressors is important too. Together, they help in achieving the coequal goal of a healthier Delta ecosystem.

Riparian and Shaded Riverine Aquatic Habitat

Fish and birds migrating through the Delta need abundant floodplains and appropriate water flows; but they also need streamside trees and shrubs that shade and cool the rivers; undercut riverbanks where smolts and other small fish rest and hide; and trees that drop insects and leaves that contribute to the food web and provide cover, food, and nest sites for songbirds and other wildlife. Unfortunately, along most of the Sacramento and San Joaquin rivers, levees are near the water's edge, not set back from rivers, leaving little room for these habitat features, which often are provided only by trees growing immediately adjacent to or even on the levees themselves.

Because of the importance of these streamsides, water supply or flood risk policies and projects that affect the Delta's rivers and other channels should consider the impact on remaining riparian and shaded riverine habitat. Setting back levees can create additional area for habitat and increased capacity for flood flows. Setting back levees, however, can be expensive and difficult. At the same time, there is considerable controversy over the current policy of the U.S. Army Corps of Engineers (USACE) to require removal of trees and most shrubs from levees under their jurisdiction. A technical manual issued by the Federal Emergency Management Agency (FEMA) for earthen dams has been relied upon heavily to support this vegetation removal policy (FEMA 2005). There is little riverine habitat left. If implemented as proposed, the USACE's order would destroy much of what remains. The Delta Plan calls for the

USACE to reconsider and change its policy in order to protect riverine habitat.

Safe Harbor Agreements

Voluntary safe harbor agreements between wildlife agencies and landowners can contribute to the recovery of species protected by the State or federal Endangered Species Acts. These agreements assure the landowners that the presence of endangered species on their property will not result in restrictions on other activities undertaken on their land. Facilitating and creating standard rules for these agreements with Delta landowners may encourage more landowners to participate in conservation programs.

Suisun Marsh and the Bay Conservation and Development Commission

The Suisun Marsh is one of the Delta Plan's priority habitat restoration areas. It is one of the largest contiguous estuarine wetlands in North America; an important nursery for fish; a wintering and nesting area for waterfowl and waterbirds; and an essential habitat for plants, fish, and wildlife, including several scarce and sensitive species. Suisun Marsh offers unique restoration opportunities because of its position in the Delta ecosystem and the diversity of physical processes it hosts. Suisun Marsh harbors a greater percentage of native fish than the remainder of the Delta, in part because its brackish water limits nonnative species. Additionally, the marsh has many diverse tidal sloughs that provide options for food and refuge (Moyle et al., 2010).

Unlike the deeply subsided Delta, much of the Suisun Marsh is still at elevations suitable for restoration of intertidal habitat, including tidal marsh and shallow water habitat. This area provides the brackish portion of the estuary with the potential to support productive and complex food webs, and with space to adapt to sea level rise. State and local land use policies should reflect the unique role that Suisun Marsh can play.

The San Francisco Bay Conservation and Development Commission (BCDC) is responsible for protecting San Francisco Bay and its shoreline, including Suisun Marsh, through the San Francisco Bay Plan, as described in Chapter 5. It is developing regional strategies to address the impacts of sea level rise and climate change on the Bay. BCDC provides special protection of the Suisun Marsh under the Suisun Marsh Preservation Act through the Suisun Marsh Protection Plan (SMPP). BCDC recently amended the San Francisco Bay Plan to address climate change and sea level rise. The climate change policy, among other things, incorporates sea level rise projection ranges consistent with those developed by the California Ocean Protection Council (2011) and calls for development of a long-term regional strategy to address sea level rise and storm activity. The SMPP and the Suisun Marsh Local Protection Program should also be amended to address climate change and rising sea level.

Ecosystem Water Quality

Chapter 6 deals with water quality issues and contains many recommendations for action. Impaired water quality makes it much harder to restore a healthy Delta ecosystem. Recommendations in Chapter 6 regarding salinity and environmental water quality cover key linkages between ecosystem restoration and water quality.

Consistently good water quality is crucial for successful restoration of aquatic habitats, sustenance of native plants and animals, and other beneficial uses of Delta water. Salinity should be more consistent, with a naturally variable estuarine hydrograph with high-quality river inflows. Nutrient composition and concentrations should not cause excessive growth of nuisance aquatic plants or blooms of harmful algae, and should support diverse and productive aquatic food webs. Dissolved oxygen levels, water temperatures, turbidity, and other attributes should meet the needs of native species. At all times the Delta should be free of substances that exceed toxic concentrations. Discharge of treated wastewater, urban runoff, or agricultural return flows should not adversely affect the Delta.

Chapter 6 focuses on four key areas where the best available science shows the need to protect and improve water quality to achieve the coequal goals (see Chapter 6 for a complete discussion):

- Requiring Delta-specific water quality protection
- Protecting beneficial uses by managing salinity
- Improving drinking water quality
- Improving environmental water quality

Nonnative Species

Among the world's estuaries, the Delta and San Francisco Bay are among the most invaded by nonnative species (Cohen and Carlton 1998). Some nonnative species have been in the Delta for more than a century and seem to be a permanent feature of the Delta ecosystem. Because it is nearly impossible to eradicate nonnative species once they are established, many can be considered legacy stressors that can be managed but not eliminated.

However, the introduction of any new nonnative species has consequences, particularly for native species. Nonnatives can take over habitat space, compete for food and nutrients, alter food webs, modify the physical habitat structure, or prey upon native species (DFG 2011). In wetlands and riparian areas, nonnative vegetation often crowds out native plants and reduces diversity used by resident and migrating birds and other animals (PRBO CalPIF 2008). The result is that nonnative plants, invertebrates, and fish may replace native species, and that change on their native counterparts is often combined with the other stressors such as altered flow, impaired habitat, and poor water quality.

Significant nonnative species in the Delta include (DFG 2008):

- **Overbite clam.** The overbite clam, a bottom-dwelling filter feeder, entered the Delta in the late 1980s and adapted well to its brackish areas. Overbite clams contribute to the reduction of algae and some invertebrates in the Delta, especially in Suisun Bay (Kimmerer 2006), causing loss at the base of the food web, which contributes to the decline of delta smelt and other open-water fish (Sommer et al. 2007).
- **Asian clam.** The Asian clam was first found in the Delta in 1946 (USGS 2001). This clam does not tolerate saline water, but is abundant in freshwater parts of the Delta and in the mainstems of the Sacramento and San Joaquin rivers. Ecologically, this species can alter channel bottoms and competes with native freshwater mussels for food and space (Claudi and Leach 2000). Overbite and Asian clams cannot be effectively controlled, according to many experts (Healey et al. 2008), but they may be managed by manipulating environmental conditions such as flow or salinity to seasonally control their distribution.
- **Zooplankton.** Surveys of Delta waters reveal that introduced zooplankton, probably discharged in ocean ship ballast water in the San Francisco Bay and Delta, have almost completely replaced the original native zooplankton (Winder and Jassby 2011). The success of nonnative zooplankton species was accompanied by an overall decline in zooplankton biomass and size that suggests a decrease in their nutritional value for fish (Winder and Jassby 2011).
- **Nonnative invasive aquatic plants.** The floating water hyacinth, imported as a landscaping plant, proliferated in the Delta in the early 1980s. The Brazilian waterweed was introduced in the 1960s, probably from home aquariums, but did not reach nuisance levels until after the 1987-1992 drought (Jassby and Cloern 2000). These and other nonnative aquatic weeds in the Delta, including water pennywort, Eurasian water milfoil, and parrot feather, pose serious problems to native plants and animals, and hinder boating. The weeds flourish in a wide area where they act as powerful "ecosystem engineers" (Jones et al. 1994, Breitburg et al. 2010) through alteration of habitats, sometimes creating dense mats or thickets that displace native plants, reduce the food web

productivity, reduce turbidity, and interfere with water conveyance and flood control facilities. These invasive plants benefit nonnative predatory fish like largemouth bass. Areas of dense, submerged aquatic vegetation (SAV) may reduce the abundance of native fish larvae and adults (Grimaldo et al. 2004, Nobriga et al. 2005, Brown and Michniuk 2007). Restoration of aquatic habitats must be designed and managed to reduce nonnative SAV if conservation goals are to be met (Nobriga and Feyrer 2007).

- **Bass and sunfish.** Several species of nonnative fish have been introduced in the Delta. Largemouth and smallmouth bass, sunfish including bluegills and warmouth, crappies, and other fish in the centrarchid family are the best examples. They prey on salmon smolts, smelt, and other native fish. The increase in SAV, especially in and around "flooded islands" in the central Delta, enhances bass and bluegill populations (Brown and Michniuk 2007) and possibly populations of other nonnative predators (Grimaldo et al. 2009). Centrarchids harm native fish through predation and competition (Nobriga and Feyrer 2007, Brown and Michniuk 2007). The distribution of centrarchids may be modified by managing conditions such as water velocity, nutrients, salinity, and turbidity to reduce SAV.

The invasion of nonnative species is in the category of globally determined stressors because these species' arrival in the Delta is the result of large-scale natural processes and human activities that are beyond the purview of the Delta Plan. Nonnative species have persisted because they found favorable environments in which to live. Native species are adapted to the varied, complex floodplains, marshes, and other habitats of the historical Delta, with its tidal currents and river flows that constantly change physical, chemical, and biological conditions. In contrast, the stabilized flow pattern, altered habitats, and impaired water quality of the modern Delta often favor nonnative species. Reducing the impacts of nonnative species in the Delta will require addressing flow alterations, pollution (especially nutrients), and physical habitat characteristics.

Future invasions by zebra and quagga mussels are likely and will require considerable preparation, followed by interagency coordination and action. These mussels are an example of an "anticipated stressor" under the Delta ISB's classification of stressor types. Neither has been observed in the Delta yet, but they have proven to be highly invasive when conditions are right. They pose threats comparable to threats from the overbite and Asian clams. They can colonize hard and soft surfaces, often in large densities (greater than 2,800 individuals per square foot) that impede the flow of water through canals and pipes. These mussels also remove particulates in the water, unnaturally enhancing water clarity.

Once introduced, nonnative species are difficult and expensive to control, and often impossible to eradicate. The California Department of Boating and Waterways supports programs to control Brazilian waterweed and water hyacinths where they hinder boating, but only where conditions create the worst nuisances. The best way to prevent new infestations is to avoid the introduction of new species. Improvements in managing ballast water by shipping companies have been instituted recently, but likely more needs to be done.

There is no agreement about the value—or lack of value—of nonnative species. Opinions vary depending on the species and the interest of Delta users. Striped bass are nonnative but prized for their sport and economic value. Introduced to the Delta in the nineteenth century, they prey on native open-water fish such as delta smelt, longfin smelt, and juvenile salmon and steelhead. Striped bass are at the center of an ongoing debate about whether fishing regulations for introduced species should conserve the fish or should be less restrictive to reduce their abundance (DFG 2011).

The draft Ecosystem Restoration Program (ERP) Conservation Strategy acknowledges that many nonnative species will likely remain in the Delta, and emphasizes prevention and adaptation strategies such as public education, preventing establishment of additional nonnative species, and reducing the impacts of established nonnative species. DFW issued its *California Aquatic Invasive Species Management Plan* in 2008, which aims to coordinate the various State efforts to minimize harmful ecological, economic, and human health impacts from aquatic invasive species (DFG 2008).

Hatcheries and Harvest Management

In the Delta, people have harvested fish and shellfish for millennia. Today, fishing, crabbing, crawdadding, and clamming are important recreation activities. Central Valley salmon—most raised in hatcheries—migrate through the Delta and support an economically and culturally important coastal fishery. In the Delta and its tributary rivers, recreational fishing for salmon, sturgeon, striped bass, largemouth bass, shad, and other fish attracts anglers from throughout California and the world. Fishing in the Delta is a centerpiece of the unique cultural, recreational, and natural heritage that makes the Delta a special place (see Chapter 5).

The use of hatcheries to breed fish and regulations to limit overfishing have long been important tools for aquatic resource management. But they carry their own risk. Hatcheries can allow interbreeding, weakening the genetic fitness of a fish species (Israel et al. 2011). Harvest of hatchery-enhanced fish stocks can pose additional risks to native species. Overfishing itself reduces genetic diversity. Fishing regulations generally protect fish from overharvest, but regulations can also help or hurt other fish species. For example, DFW recently proposed changes to striped bass sport fishing regulations to allow greater harvest of striped bass in the hopes of reducing bass predation on native fish, especially salmon. These changes were rejected by the Fish and Game Commission, but it is likely other regulations will be recommended, particularly as the emphasis on saving native fish from nonnative invasives continues. Future proposals should be based on an improved understanding of anglers' behavior as well as a better understanding of the likely response in populations of striped bass and other predators. Harvest regulations and management practices must consider broader effects on nontarget species, including other predators, and the ecosystem.

Striped bass, for example, are not the only animals that prey on salmon. Predators are natural parts of any ecosystem, and predation is a basic ecosystem process. Fish predators in the Delta include many water birds, mammals, and fish such as native pikeminnows and introduced largemouth bass, smallmouth bass, striped bass, catfish, and other species. Nonnative fish consume salmon and other species of concern in the Delta and its tributaries (Lindley and Mohr 2003). Acoustic tagging studies in the San Joaquin River and southern Delta suggest significant predation on hatchery-reared salmon smolts. Survival of tagged salmon smolts released in the lower San Joaquin River was estimated to be only 5 percent in 2010, with much of the loss attributed to predation (San Joaquin River Group Authority 2010). However, despite the evidence of locally high predation, the overall contribution of predation to the decline of salmon, steelhead, and smelt populations is not clear, and the effect of predator controls will remain uncertain without additional study.

Hatchery Management

Another important tool for harvest management is raising fish in hatcheries, later to be released into natural waterways.

In California, hatcheries are particularly important to compensate for dams that block migration routes for salmon and steelhead (see previous Ecosystem Restoration section). The first salmon hatchery in the state was on the McCloud River. Today, California hosts two federal and twenty-one State hatcheries for salmon, steelhead, or trout. In recent years, "conservation hatcheries" for various threatened and endangered species were considered to prevent extinction of a species while restoration and stressor reduction activities are under way.

Hatcheries are important tools, but they involve genetic and ecological risks:

- **Genetic risks.** Human intervention in the rearing of wild animals has the potential to cause genetic change in fish such as salmon (Israel et al. 2011). These changes can impact fish diversity and the health of fish populations. Inbreeding in a fish hatchery can occur when a limited stock is used at the hatchery. Inbreeding can affect the survival, growth, and reproduction of fish. Ironically, conditions in the hatchery may favor fish that best survive in hatchery, not natural, environments. When released, hatchery-produced fish mix with naturally spawned fish, resulting in a lower survival rate once fish are released into rivers and streams. Finally, loss of genetic diversity is a documented effect of overfishing (Holmes 2011), which some have suggested is encouraged by the use of hatchery fish.

- **Ecological risks.** Wild and hatchery fish of the same species often compete in nature. For example, wild and hatchery-reared Chinook salmon share the same habitat and diet. Hatchery-released salmon are larger than wild salmon, resulting in possible predation on wild salmon of the same age. Hatchery production of salmon masks the decline of wild salmon, contributes to the genetic dilution and loss of wild salmon, and increases competition for limited freshwater and ocean resources on which wild salmon depend (McGinnis 1994). Throughout the world, overfishing has led to collapsing fish stocks and food web disruptions (Pauly et al. 1998). Hatchery and harvest effects often also interact. Harvest of salmon from waters where both hatchery and wild fish occur has put wild salmon and steelhead at risk (Lackey 2003). Wild salmon mortalities occur even with controlled fishing regulations. A portion of all fish released after being hooked and caught do not survive. Capture methods such as use of barbless hooks and use of landing nets can help reduce mortality of released fish.

Hatcheries and harvest are not the root problem of species declines in the Delta and Central Valley (DFG and NMFS 2001). Despite considerable fishing pressure in the first part of the twentieth century, striped bass, salmon, and steelhead remained abundant in California. Large declines followed the construction of dams on almost all Central Valley rivers, which greatly reduced access to spawning and rearing habitat. Once fish populations are low and habitat is damaged, their harvest can be an especially important control factor. Hatcheries were intended to substitute for lost spawning and rearing habitat, but nature cannot be so easily mimicked. Artificial propagation can provide abundant fish for restocking, but it cannot replace the abundance, productivity, life history diversity, and broad distribution of viable populations. Successful hatchery propagation will work best if it goes hand in hand with habitat restoration. Ultimately, fish produced in hatcheries must thrive and naturally reproduce once they have left the hatchery (Israel et al. 2011). Accordingly, close attention needs to be paid to genetic management to reduce genetic risks.

Hatchery and harvest regulations, and management practices related to those regulations must be based on the best available science and follow adaptive management protocols for monitoring and evaluating the results. Evaluations of hatchery fish impacts would be aided by better hatchery fish-marking techniques and more extensive marking.

POLICIES AND RECOMMENDATIONS

Policies and recommendations for restoring the Delta ecosystem include the following core strategies to reduce the impact of ecosystem stressors:

- Create more natural functional Delta flows
- Restore habitat
- Improve water quality to protect the ecosystem
- Prevent introduction of and manage nonnative species impacts
- Improve hatcheries and harvest management

Success of Delta ecosystem restoration depends on considering and addressing all stressor categories as well as completing and implementing the BDCP described in Chapter 3. Because reducing or eliminating some stressors, especially the globally determined and legacy stressors, will be difficult, adaptation to unmitigable stressors is also imperative.

Create More Natural Functional Flows

Water flow in the Delta is critically important because flow affects the reliability of water supplies and the health of the Delta ecosystem. The best available science demonstrates that flow management is essential to restoration of the Delta ecosystem. Several important ecosystem stressors, including entrainment, are linked to altered water flows. Greater reverse flows in the south Delta increase the numbers of fish entrained.

Problem Statement

Altered flows in the Sacramento and San Joaquin rivers and their tributaries change flows within and out of the Delta, and affect salinity and sediment in the Delta. Fish and other aquatic species native to the Delta are adapted to natural flow, salinity, and sediment regimes. Current flow, salinity, and sediment regimes harm native aquatic species and encourage nonnative species. The best available science suggests that currently required flow objectives within and out of the Delta are insufficient to protect the Delta ecosystem (SWRCB 2010). Additionally, uncertainty regarding future flow objectives for the Delta impairs the reliability of water supplies that depend on the Delta or its watershed. The predictability of water exports cannot be improved, and the BDCP cannot be implemented without timely SWRCB action to update flow objectives.

Policy

ER P1. Delta Flow Objectives

(a) *The State Water Resources Control Board's Bay Delta Water Quality Control Plan flow objectives shall be used to determine consistency with the Delta Plan. If and when the flow objectives are revised by the State Water Resources Control Board, the revised flow objectives shall be used to determine consistency with the Delta Plan.*

(b) *For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, the policy set forth in subsection (a) covers a proposed action that could significantly affect flow in the Delta.*

23 CCR Section 5005
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85054, 85086, 85087, 85300, and 85302, Water Code.

Recommendations

ER R1. Update Delta Flow Objectives

Development, implementation, and enforcement of new and updated flow objectives for the Delta and high-priority tributaries are key to the achievement of the coequal goals. The State Water Resources Control Board should update the Bay Delta Water Quality Control Plan objectives as follows:

(a) *By June 2, 2014, adopt and implement updated flow objectives for the Delta that are necessary to achieve the coequal goals.*

(b) *By June 2, 2018, adopt, and as soon as reasonably possible, implement flow objectives for high-priority tributaries in the Delta watershed that are necessary to achieve the coequal goals.* [1]

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[1] SWRCB staff should work with the Council and DFW to determine priority streams. As an illustrative example, priority streams could include the Merced River, Tuolumne River, Stanislaus River, Lower San Joaquin River, Deer Creek (tributary

Flow objectives could be implemented through several mechanisms including negotiation and settlement, Federal Energy Regulatory Commission relicensing, or adjudicative proceeding. [2]

Prior to the establishment of revised flow objectives identified above, the existing Bay Delta Water Quality Control Plan objectives shall be used to determine consistency with the Delta Plan. After the flow objectives are revised, the revised objectives shall be used to determine consistency with the Delta Plan.

Restore Habitat

Loss of habitat is one of the largest stressors to the Delta ecosystem. The Delta Plan adopts the approach of the multiagency ERP Conservation Strategy (DFG 2011), which includes a map and accompanying text identifying appropriate habitat restoration types within the Delta and Suisun Marsh based on land elevation, included in the Delta Plan within Appendix B. Delta Plan Figure 4-6 is based on the ERP Conservation Strategy map. Policy ER P3 requires habitat restoration actions to use this figure and accompanying text (see Appendix B for additional information). For example, restoring tidal marsh habitat would generally not be appropriate outside the areas labeled “intertidal” on Figure 4-6 unless they connect other tidal marshes into large habitat areas or can recover elevation over time by natural processes.

An integrated, adaptive approach to restoring habitat must address several issues. Each problem statement below highlights one of these issues, followed by specific policies and recommendations intended to address it.

Problem Statement

Features of the Delta landscape, particularly the condition of its waterways, the elevation of its land, and other environmental conditions, have changed dramatically over the past 160 years. Damage to the habitats that support native species in the Delta has led to declines in native animal and plant populations, affecting both resident and migratory species.

Policies

The appendices referred to in the policy language below are included in Appendix B of the Delta Plan.

ER P2. Restore Habitats at Appropriate Elevations

(a) *Habitat restoration must be carried out consistent with Appendix 3, which is Section II of the* Draft Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions *(California Department of Fish and Wildlife 2011). The elevation map attached as Appendix 4 should be used as a guide for determining appropriate habitat restoration actions based on an area’s elevation. If a proposed habitat restoration action is not consistent with Appendix 4, the proposal shall provide rationale for the deviation based on best available science.*

(b) *For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that includes habitat restoration.*

23 CCR Section 5006
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85022, 85054, 85300, and 85302, Water Code.

ER P3. Protect Opportunities to Restore Habitat

(a) *Within the priority habitat restoration areas depicted in Appendix 5, significant adverse impacts to the opportunity to restore habitat as described in section 5006, must be avoided or mitigated.*

(b) *Impacts referenced in subsection (a) will be deemed to be avoided or mitigated if the project is designed and implemented so that it will not preclude or otherwise interfere with the ability to restore habitat as described in section 5006.*

(c) *Impacts referenced in subsection (a) shall be mitigated to a point where the impacts have no significant effect on the opportunity to restore habitat as described in section 5006. Mitigation shall be determined, in consultation with the California Department of Fish and Wildlife, considering the size of the area impacted by the covered action and the type and value of habitat that could be restored on that area, taking into account existing and proposed restoration plans, landscape attributes, the elevation map shown in Appendix 4, and other relevant information about habitat restoration opportunities of the area.*

(d) *For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions in the priority habitat restoration areas depicted in Appendix 5. It does not cover proposed actions outside those areas.*

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to Sacramento River), Lower Butte Creek, Mill Creek (tributary to Sacramento River), Cosumnes River, and American River. Implementation through hearings is expected to take longer than the deadline shown here.

[2] Implementation through adjudicative proceedings or FERC relicensing is expected to take longer than the deadline shown here.

23 CCR Section 5007
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85022, 85054, 85300, 85302, and 85305, Water Code.

Figure 4-7 provides examples of ways a project can implement ER P3.

ER P4. Expand Floodplains and Riparian Habitats in Levee Projects

(a) *Levee projects must evaluate and where feasible incorporate alternatives, including the use of setback levees, to increase floodplains and riparian habitats. Evaluation of setback levees in the Delta shall be required only in the following areas (shown in Appendix 8): (1) The Sacramento River between Freeport and Walnut Grove, the San Joaquin River from the Delta boundary to Mossdale, Paradise Cut, Steamboat Slough, Sutter Slough; and the North and South Forks of the Mokelumne River, and (2) Urban levee improvement projects in the cities of West Sacramento and Sacramento.*

(b) *For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action to construct new levees or substantially rehabilitate or reconstruct existing levees.*

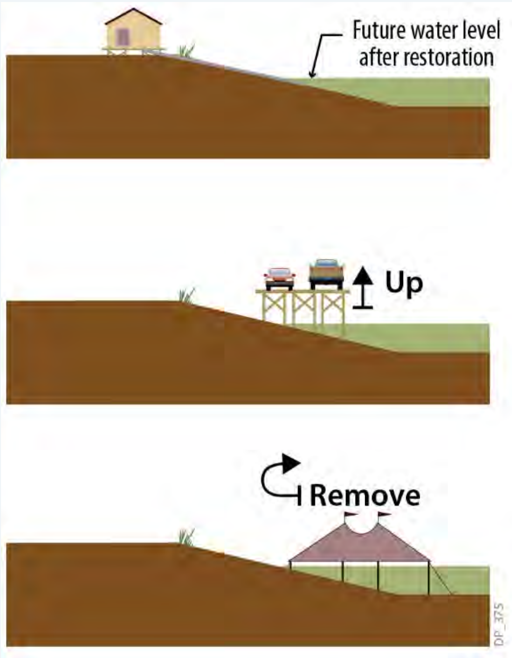
23 CCR Section 5008
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85022, 85054, 85300, 85302, and 85305, Water Code.

Recommendations

ER R2. Prioritize and Implement Projects that Restore Delta Habitat

Bay Delta Conservation Plan implementers, California Department of Fish and Wildlife, California Department of Water Resources, and the Delta Conservancy should prioritize and implement habitat restoration projects in the areas shown on Figure 4-8. Habitat restoration projects should ensure connections between areas being restored and existing habitat areas and other elements of the landscape needed for the full life cycle of the species that will benefit from the restoration project. Where possible, restoration projects should also emphasize the potential for improving water quality. Restoration project proponents should consult the California Department of Public Health's Best Management Practices for Mosquito Control in California.

How Projects Can Comply with ER P3



Locate structures at the edge of a habitat restoration area, rather than in the middle, to improve opportunities for restoring habitat connectivity.

Elevate structures so that water can flow underneath to allow for restoration of aquatic habitat dependent on tides or periodic flooding.

Allow temporary uses and require the removal of structures and cleanup afterward to protect opportunities for habitat restoration.

Figure 4-7

ER P3 requires projects located in the priority habitat restoration areas (shown on Figure 4-8) to protect opportunities to restore habitat. This figure shows conceptual examples of how to implement this policy.

Recommended Areas for Prioritization and Implementation of Habitat Restoration Projects

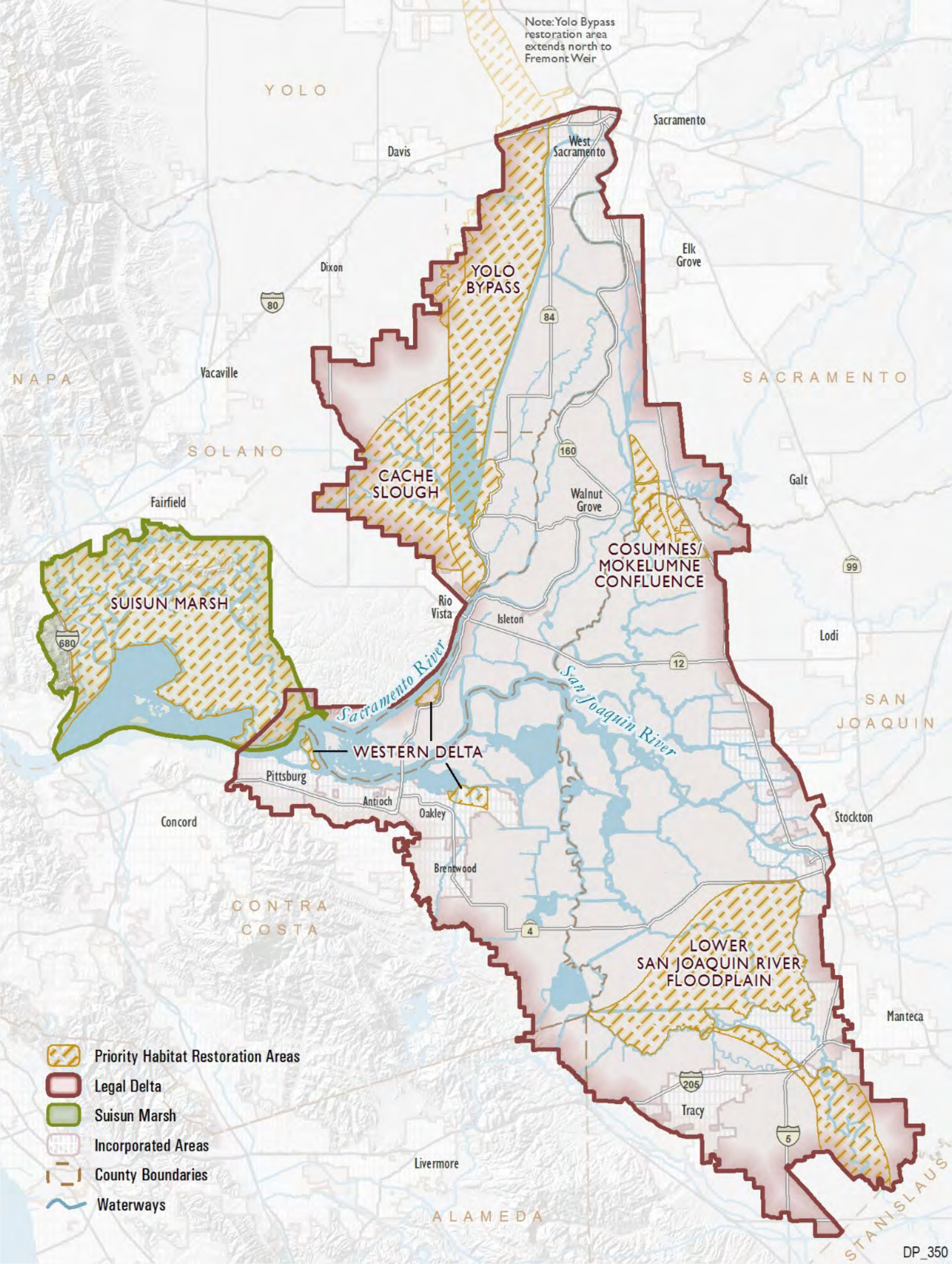


Figure 4-8

Priority habitat restoration areas are large areas within which specific sites may be identified for habitat restoration based on assessments of land use and other issues addressed through further feasibility analysis.

Source: DFG 2011

- ***Yolo Bypass.*** *Enhance the ability of the Yolo Bypass to flood more frequently to provide more opportunities for migrating fish, especially Chinook salmon, to use this system as a migration corridor that is rich in cover and food.*
- ***Cache Slough Complex.*** *Create broad nontidal, freshwater, emergent-plant-dominated wetlands that grade into tidal fresh-water wetlands, and shallow subtidal and deep open-water habitats. Also, return a significant portion of the region to uplands with vernal pools and grasslands.*
- ***Cosumnes River–Mokelumne River confluence.*** *Allow these unregulated and minimally regulated rivers to flood over their banks during winter and spring frequently and regularly to create seasonal floodplains and riparian habitats that grade into tidal marsh and shallow subtidal habitats.*
- ***Lower San Joaquin River floodplain.*** *Reconnect the floodplain and restore more natural flows to stimulate food webs that support native species. Integrate habitat restoration with flood management actions, when feasible.*
- ***Suisun Marsh.*** *Restore significant portions of Suisun Marsh to brackish marsh with land-water interactions to support productive, complex food webs to which native species are adapted and to provide space to adapt to rising sea level action. Use information from adaptive management processes during the* Suisun Marsh Habitat Management, Preservation, and Restoration Plan's *implementation to guide future habitat restoration projects and to inform future tidal marsh management.*
- ***Western Delta/Eastern Contra Costa County.*** *Restore tidal marsh and channel margin habitat at Dutch Slough and western islands to support food webs and provide habitat for native species.*

ER R3. Complete and Implement Delta Conservancy Strategic Plan

As part of its Strategic Plan and subsequent Implementation Plan or annual work plans, the Delta Conservancy should:

- *Develop and adopt criteria for prioritization and integration of large-scale ecosystem restoration in the Delta and Suisun Marsh, with sustainability and use of best available science as foundational principles.*
- *Develop and adopt processes for ownership and long-term operations and management of land in the Delta and Suisun Marsh acquired for conservation or restoration.*
- *Develop and adopt a formal mutual agreement with the California Department of Water Resources, California Department of Fish and Wildlife, federal interests, and other State and local agencies on implementation of ecosystem restoration in the Delta and Suisun Marsh.*
- *Develop, in conjunction with the Wildlife Conservation Board, the California Department of Water Resources, California Department of Fish and Wildlife, Bay Delta Conservation Plan implementers, and other State and local agencies, a plan and protocol for acquiring the land necessary to achieve ecosystem restoration consistent with the coequal goals and the Ecosystem Restoration Program Conservation Strategy.*
- *Lead an effort, working with State and federal fish agencies, to investigate how to better use habitat credit agreements to provide credit for each of these steps: (1) acquisition for future restoration; (2) preservation, management, and enhancement of existing habitat; (3) restoration of habitat; and (4) monitoring and evaluation of habitat restoration projects.*
- *Work with the California Department of Fish and Wildlife and the U.S. Fish and Wildlife Service to develop rules for voluntary safe harbor agreements with property owners in the Delta whose actions contribute to the recovery of listed threatened or endangered species.*

Problem Statement

Current USACE policy requires removal of vegetation from Delta levees, which would reduce already sparse riparian and shaded aquatic habitat along the channels.

Policies

No policies with regulatory effect are included in this section.

Recommendation

ER R4. Exempt Delta Levees from the U.S. Army Corps of Engineers' Vegetation Policy

Considering the ecosystem value of remaining riparian and shaded riverine aquatic habitat along Delta levees, the U.S. Army Corps of Engineers should agree with the California Department of Fish and Wildlife and the California Department of Water Resources on a variance that exempts Delta levees from the U.S. Army Corps of Engineers' levee vegetation policy where appropriate.

Problem Statement

The SMPP and the Local Protection Program components of the SMPP do not yet include climate change provisions. Without these amendments, it is unclear if and how Suisun Marsh will be managed to adapt to rising sea level.

Policies

No policies with regulatory effect are included in this section.

Recommendation

ER R5. Update the Suisun Marsh Protection Plan

The San Francisco Bay Conservation and Development Commission should update the Suisun Marsh Protection Plan *and relevant components of the Suisun Marsh Local Protection Program to adapt to sea level rise and ensure consistency with the Suisun Marsh Preservation Act, the Delta Reform Act, and the Delta Plan.*

Improve Water Quality to Protect the Ecosystem

Chapter 6 includes recommendations about salinity and ecosystem water quality. These recommendations support the protection of water quality for all beneficial uses of water and encourage the identification of water quality impacts of proposed actions. The recommendations also address acceleration of certain total maximum daily loads, low dissolved oxygen, implementation of a Delta Regional Monitoring Program, treatment of wastewater effluent and urban runoff, and Regional Water Quality Control Board engagement in Suisun Marsh.

Problem Statement

The Delta ecosystem is impaired by pollutants from municipal, industrial, agricultural, and other discharges and legacy pollutants flowing into the Delta and its tributaries, including pollutants that bioaccumulate and biomagnify in the food web.

Policies

No policies with regulatory effect are included in this section.

Recommendations

Recommendations for improving ecosystem water quality are included in Chapter 6.

Prevent Introduction of and Manage Nonnative Species Impacts

Problem Statement

Nonnative species are a major obstacle to successful restoration of the Delta ecosystem because they affect the survival, health, and distribution of native Delta wildlife and plants. There is little chance of eradicating most established nonnative species, but management can reduce the abundance of some. The resilience of native species is reduced by ongoing introductions of nonnative species and management actions that enhance conditions for nonnative species.

Policy

ER P5. Avoid Introductions of and Habitat Improvements for Invasive Nonnative Species

(a) The potential for new introductions of or improved habitat conditions for nonnative invasive species, striped bass, or bass must be fully considered and avoided or mitigated in a way that appropriately protects the ecosystem.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that has the reasonable probability of introducing or improving habitat conditions for nonnative invasive species.

23 CCR Section 5009
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85054, 85300, and 85302, Water Code.

Recommendations

ER R6. Regulate Angling for Nonnative Sport Fish to Protect Native Fish

The California Department of Fish and Wildlife should develop, for consideration by the Fish and Game Commission, proposals for new or revised fishing regulations designed to increase populations of listed fish species through reduced predation by introduced sport fish. The proposals should be based on sound science that demonstrates these *management actions are likely to achieve their intended outcome and include the development of performance measures and a monitoring plan to support adaptive management.*

ER R7. Prioritize and Implement Actions to Control Nonnative Invasive Species

The California Department of Fish and Wildlife and other appropriate agencies should prioritize and fully implement the list of "Stage 2 Actions for Nonnative Invasive Species" and accompanying text shown in Appendix J taken from the Conservation Strategy for Restoration of the Sacramento–San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions *(DFG 2011). Implementation of the Stage 2 actions should include the development of performance measures and monitoring plans to support adaptive management.*

Improve Hatcheries and Harvest Management

Problem Statement

Hatcheries and harvest regulation are important tools in fisheries management, but they also pose genetic and ecological risks to native species and the Delta ecosystem. These practices need to employ adaptive management strategies to predict and evaluate outcomes, and minimize risks.

Policies

No policies with regulatory effect are included in this section.

Recommendations

ER R8. Manage Hatcheries to Reduce Genetic Risk

As required by the National Marine Fisheries Service, all hatcheries providing listed fish for release into the wild should continue to develop and implement scientifically sound Hatchery and Genetic Management Plans (HGMPs) to reduce risks to those species. The California Department of Fish and Wildlife should provide annual updates to the Delta Stewardship Council on the status of HGMPs within its jurisdiction.

ER R9. Implement Marking and Tagging Program

By December 2014, the California Department of Fish and Wildlife, in cooperation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, should revise and begin implementing its program for marking and tagging hatchery salmon and steelhead to improve management of hatchery and wild stocks based on recommendations of the California Hatchery Scientific Review Group, which considered mass marking, reducing hatchery programs, and mark selective fisheries in developing its recommendations.

Timeline for Implementing Policies and Recommendations

Figure 4-9 lays out a timeline for implementing the policies and recommendations described in the previous section. The timeline emphasizes near-term and intermediate-term actions.

Timeline for Implementing Policies and Recommendations

TIMELINE CHAPTER 4: Ecosystem Implementation

	ACTION (REFERENCE #)	LEAD AGENCY(IES)	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025
POLICIES	Delta flow objectives (ER P1)	SWRCB	●	●
	Restore habitats at appropriate elevations (ER P2)	DFW, DWR, Delta Conservancy	●	●
	Protect opportunities to restore habitat (ER P3)	DFW	●	●
	Expand floodplains and riparian habitats in levee projects (ER P4)	DWR, USACE	●	●
	Avoid introductions of and habitat improvements for invasive nonnative species (ER P5)	DFW, DWR, Delta Conservancy	●	●
RECOMMENDATIONS	Update Delta flow objectives (ER R1)	SWRCB	●	●
	Prioritize and implement projects that restore Delta habitat (ER R2)	DFW, DWR, and Delta Conservancy	●	●
	Complete and implement Delta Conservancy Strategic Plan (ER R3)	Delta Conservancy	●	
	Exempt Delta levees from U.S. Army Corps of Engineers' Vegetation Policy (ER R4)	USACE, DWR, DFW	●	●
	Update the Suisun Marsh Protection Plan (ER R5)	BCDC	●	
	Regulate angling for nonnative sport fish to protect native fish (ER R6)	DFW, CA Fish and Game Commission	●	
	Prioritize and implement actions to control nonnative invasive species (ER R7)	DFW	●	●
	Manage hatcheries to reduce genetic risk (ER R8)	DFW	●	●
	Implement marking and tagging program (ER R9)	DFW	●	●

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Agency Key:

BCDC: San Francisco Bay Conservation and Development Commission
BDCP: Bay Delta Conservation Plan
Delta Conservancy: Sacramento-San Joaquin Delta Conservancy
Council: Delta Stewardship Council
DFW: California Department of Fish and Wildlife
DWR: California Department of Water Resources
RWQCB: Regional Water Quality Control Board(s)
SWRCB: State Water Resources Control Board
USACE: U.S. Army Corps of Engineers

Figure 4-9

Issues for Future Evaluation and Coordination

Additional areas of interest and concern related to the Delta ecosystem may deserve consideration in the development of future Delta Plan updates:

- **Landscape-scale conceptual models.** The Delta Science Program will collaborate with other agencies, academic institutions, and stakeholders to develop landscape-scale conceptual models for the six priority restoration areas identified in ER R2.
- **Workshops to address stressor impacts.** The Delta Science Program, in collaboration with other agencies, academic institutions, and stakeholders, will hold workshops to develop additional recommendations to the Council for measures to reduce stressor impacts on the Delta ecosystem that would support and be consistent with the coequal goals. Recommended measures could be adopted as policies or recommendations by the Council into an amended Delta Plan.
- **Above-the-Delta migration corridors.** The Council will consult with fish and wildlife agencies and others as they complete or update plans to restore habitats for migratory species, such as anadromous fish or songbirds in the Sacramento and San Joaquin valleys above the Delta.

Science and Information Needs

The Delta ecosystem is not static; therefore, additional information is needed for decision making and adaptive management. Specifically, the following information is needed in the following areas:

- Landscape-scale conceptual models for Delta ecosystem restoration.
- Assessment of how flows benefit or harm native wildlife and plants.
- Effects of changing habitat quality and quantity on Delta fish and invertebrates. Examples might include (1) threadfin shad in the south and central Delta, (2) comparison of shallow shoal habitat and deep channel habitat to food resources of young striped bass, and (3) relationship between water turbidity and native fish migration, survival, growth, and/or reproduction.
- Hatchery, harvest, and/or predation impacts on natural fish populations.
- Tools to assess native fish response to restored habitats.
- Entrainment effects on fish populations.
- Tools to assess potential impacts of climate change and sea level rise to viability of species in intertidal habitats.

Performance Measures

Development of informative and meaningful performance measures is a challenging task that will continue after the adoption of the Delta Plan. Performance measures need to be designed to capture important trends and to address whether specific actions are producing expected results. Efforts to develop and track performance measures in complex and large-scale systems like the Delta are commonly multiyear endeavors. The recommended output and outcome performance measures listed below are provided as examples and subject to refinement as time and resources allow. Final administrative performance measures are listed in Appendix E and will be tracked as soon as the Delta Plan is completed.

The Delta Reform Act specifies some performance measures for large-scale ecosystem restoration within the Delta. Ecosystem performance measures should address progress in achieving the objectives set forth in Water Code sections 85302(c) and 85302(e).

Note that performance measures for ecosystem water quality are provided in Chapter 6.

Output Performance Measures

- The SWRCB adopts Delta flow objectives by June 2, 2014. (ER R1)
- The SWRCB adopts flow objectives for the major tributaries by 2018 (or soon as reasonably possible). (ER R1)
- Pilot-scale Delta habitat restoration projects are developed and initiated in the priority areas described in ER R2 by 2015. These projects include tidal brackish and freshwater marsh as well as floodplain restoration, and have clear adaptive management plans aimed at improving outcomes and providing lessons for the development of large-scale restoration projects. Metrics: acres restored by habitat type, and lessons learned. (ER R2)
- Progress, measured in acres of restored or enhanced habitat, is being made toward the biological opinions' targets of restoring 8,000 acres of tidal marsh and 17,000 to 20,000 acres of floodplain rearing habitat. (ER R2)
- The DFW and other appropriate agencies fully implement the list of "Stage 2 Actions for Nonnative Invasive Species." (ER R7)

Outcome Performance Measures

- Progress toward restoring in-Delta flows to more natural functional flow patterns to support a healthy estuary. Metrics: results from hydrological monitoring and hydrodynamic modeling. (ER R1)
- Progress toward decreasing annual trends in both the number of new and existing aquatic and terrestrial nonnative species, and the abundance and distribution of existing aquatic and terrestrial nonnative species in the Delta over the next decade. These trends will be derived from long-term animal and plant monitoring surveys conducted by the Interagency Ecological Program agencies, the California Department of Boating and Waterways, the U.S. Department of Agriculture, the San Francisco Estuary Institute, and others. (ER P5)
- Progress toward the documented occurrence and use of protected and restored habitats and migratory corridors by native resident and migratory Delta species. Trends in occurrence, use, and performance of native species in protected and restored habitats and corridors will be upward over the next decade. These trends will be derived from animal and plant monitoring surveys that are conducted as part of adaptive management strategies for the protection and restoration of these areas. (ER R2)
- Progress toward achieving the State and federal "doubling goal" for wild Central Valley salmonids relative to 1995 levels. Trends will be derived from long-term salmonid monitoring surveys conducted by the National Marine Fisheries Service, U.S. Fish and Wildlife Service, and others. (ER R2)

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CHAPTER 5

Protect and Enhance the Unique Cultural, Recreational, Natural Resource, and Agricultural Values of the California Delta as an Evolving Place

ABOUT THIS CHAPTER

This chapter describes the unique values that distinguish the Sacramento-San Joaquin Delta (Delta) and make it a special region. It also outlines the Delta Stewardship Council's (Council) five core strategies for protecting and enhancing these values:

- Designate the Delta as a special place worthy of national and state attention
- Plan to protect the Delta's lands and communities
- Maintain Delta agriculture as a primary land use, a food source, a key economic sector, and a way of life
- Encourage recreation and tourism that allow visitors to enjoy and appreciate the Delta, and that contribute to its economy
- Sustain a vital Delta economy that includes a mix of agriculture, tourism, recreation, commercial and other industries, and vital components of state and regional infrastructure

The 2 policies and 19 recommendations to carry out these strategies are found at the end of the chapter. Protecting the Delta as a place also depends on the strategies to reduce flood and other risks to the Delta that are described in Chapter 7.

RELEVANT LEGISLATION

The Sacramento-San Joaquin Delta Reform Act of 2009 declared State policy for the resources and values of the Delta (Water Code section 85054):

> *"Coequal goals" means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.*

The Legislature declares the following objectives inherent in the coequal goals for management of the Delta (Water Code section 85020):

> *(a) Manage the Delta's water and environmental resources and the water resources of the state over the long term.*
>
> *(b) Protect and enhance the unique cultural, recreational, and agricultural values of the California Delta as an evolving place.*

Water Code section 85302(h) provides direction on the implementation of measures to promote the coequal goals and inherent objectives:

> *(h) The Delta Plan shall include recommendations regarding state agency management of lands in the Delta.*

The Delta Reform Act states (Water Code section 85022 (d)):

> *(d) The fundamental goals for managing land use in the Delta are to do all of the following:*
>
> > *(1) Protect, maintain, enhance, and, where feasible, restore the overall quality of the Delta environment and its natural and artificial resources.*
> >
> > *(2) Ensure the utilization and conservation of Delta resources, taking into account the social and economic needs of the people of the state.*
> >
> > *(3) Maximize public access to Delta resources and maximize public recreational opportunities in the Delta consistent with sound resources conservation principles and constitutionally protected rights of private property owners.*
> >
> > *(4) Encourage state and local initiatives and cooperation in preparing procedures to implement coordinated planning and development for mutually beneficial uses, including educational uses, in the Delta.*
> >
> > *(5) Develop new or improved aquatic and terrestrial habitat and protect existing habitats to advance the goal of restoring and enhancing the Delta ecosystem.*
> >
> > *(6) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.*

Public Resources Code section 29703.5 describes the Delta Protection Commission's role in providing recommendations to the Delta Stewardship Council:

> *(a) The Delta Protection Commission created pursuant to Section 29735 provides an existing forum for Delta residents to engage in decisions regarding actions to recognize and enhance the unique cultural, recreational, and agricultural resources of the Delta. As such, the commission is the appropriate agency to identify and provide recommendations to the Delta Stewardship Council on methods of preserving the Delta as an evolving place as the Delta Stewardship Council develops and implements the Delta Plan.*
>
> *(b) There is a need for the five Delta counties to establish and implement a resources management plan for the Delta and for the Delta Stewardship Council to consider that plan and recommendations of the commission in the adoption of the Delta Plan.*

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CHAPTER 5

Protect and Enhance the Unique Cultural, Recreational, Natural Resource, and Agricultural Values of the California Delta as an Evolving Place

The Delta Reform Act provides that the coequal goals of providing a more reliable water supply and protecting, enhancing, and restoring the Delta ecosystem shall be achieved in a manner that protects the unique cultural, natural, recreational, resource, and agricultural values of the Delta as an evolving place. Achieving this objective begins with recognizing the values that make the Delta a distinctive and special place:

- The Delta's geography of low-lying islands and tracts, many below the water level and shaped by sloughs, shipping channels, and rivers; tidal influences; levees; and other water controls is unique among California landscapes.
- The Delta retains a rural heritage, characterized by farms and small towns linked by navigable waterways and winding country roads.
- The Delta's agricultural economy is vital to the region and contributes to California's important agricultural economy.
- The Delta is a region where maritime ports, commercial agriculture, and expanding cities coexist with a unique native ecosystem that is home to many species of wildlife and fish.
- The Delta is a place of multicultural tradition, legacy communities, and family farms.
- The Delta provides opportunities for recreation and tourism because of its unique geography, mix of activities, and rich natural resources.

The Delta's uniqueness, however, does not exempt it from change. Increasing pressures of growing populations, shifting commodity markets, climate changes, and rising sea level will require new ways of adaptation for this region. Some changes are driven by the Delta's location at the center of California's water systems and are required to meet statewide goals of restoring the Delta's ecosystem and improving water supply reliability. Other changes may be caused by floods, earthquakes, or other events that threaten the Delta's levees and islands. Some changes can be managed by policies that shape how the Delta's traditions are honored and its history preserved; guide new development; enhance recreation and tourism; and encourage agriculture, business expansion, and economic development.

Protecting the Delta as an evolving place means accepting that change will not stop, but that the fundamental characteristics and values that contribute to the Delta's special qualities and that distinguish it from other places can be preserved and enhanced while accommodating these changes (Delta Vision Blue Ribbon Task Force 2008). It does not mean that the Delta should be a fortress, a preserve, or a museum.

The Council envisions a future where the Delta's unique qualities are recognized and honored. Agriculture will continue to thrive on the Delta's rural lands; and its cities, ports, and rural villages will be desirable places to live, work, and do business. Visitors to the region will enjoy recreation on and in its waterways, marshes, resorts, parks, and historic legacy communities. The Delta's land uses and development will be resilient, protecting the rural character of the area, reducing risks to people and property, adjusting to changing conditions, and promoting the ability to recover readily from distress. The Delta's economic vitality will provide resources to respond to change and to support the families and businesses that make the Delta home. The vision of the Delta as an evolving place also acknowledges the role of Delta residents in shaping the future of the region through active and effective participation in Delta planning and management.

Creating a Common Vision of the Delta as a Place

The Delta Reform Act recognizes not only the uniqueness of the region, but also that it is managed and influenced by many State of California (State), federal, and local agencies, often with differing views about the Delta and with overlapping and sometimes conflicting jurisdictions. Through the Delta Plan, the Council intends to foster a common vision for the future of the Delta as a place and to promote more effective coordination among these agencies. (See sidebar, Looking at the Delta.)

Fashioning this common vision has begun by drawing much of the information and many of the strategies of this chapter from these agencies' reports and recommendations, including the following documents:

- The *Proposal to Protect, Enhance, and Sustain the Unique Cultural, Historical, Recreational, Agricultural, and Economic Values of the Sacramento-San Joaquin Delta as an Evolving Place* developed by the Delta Protection Commission (DPC) (DPC 2012a)
- The DPC's *Economic Sustainability Plan for the Sacramento-San Joaquin Delta* (ESP) (DPC 2012b)
- The *Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh* (Recreation Proposal) developed by California State Parks (California State Parks 2011)
- The Sacramento-San Joaquin Delta Conservancy's (Delta Conservancy) *Strategic Plan*

The Public Resources Code (section 29703.5(a)) names the DPC as "the appropriate agency to identify and provide recommendations to the Council on methods of preserving the Delta as an evolving place." The DPC is an agency created in 1992 by the Delta Protection Act to plan for and guide natural resource conservation and enhancement in the legal Delta while sustaining agriculture and meeting increased recreational demand.

LOOKING AT THE DELTA

The Delta presents itself from three vantages that display alternative aspects of its character.

From the water, the Delta is a thicket of sloughs, rock-lined channels, and open waterways where the land lies unseen behind tall levees and riparian vegetation. This is a Delta of recreational boating and oceangoing freighters, piers and lift bridges, diversions and water control structures, fish and diving ducks, resorts and marinas.

Another view of the Delta is a predominantly rural, agricultural landscape dotted with historic villages and where waterways are hidden on the other side of the levee, to be glimpsed only from bridges and levee-top roads. This is a Delta of vineyards, orchards, farm fields, ditches, and waterfowl hunting clubs; of historic farmsteads and one-of-a-kind shops and restaurants; and of farm machinery and bicyclists.

A third view of the Delta looks out from its metropolitan areas: Stockton, Manteca, Lathrop, Tracy, Contra Costa County's shoreline suburbs, Suisun City, Fairfield, Sacramento, and West Sacramento. This is a Delta of downtowns, neighborhoods, and new suburbs; cooling summer breezes and clammy winter fog; waterfront parks and a catch of striped bass in the freezer; and ports, warehouses, offices, and other job sites.

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As provided in Water Code section 85301, the DPC developed the *Proposal to Protect, Enhance, and Sustain the Unique Cultural, Historical, Recreational, Agricultural, and Economic Values of the Sacramento-San Joaquin Delta as an Evolving Place* (DPC 2012a). This proposal was submitted to the Council for incorporation into the Delta Plan. The proposal includes a plan to recognize the Delta as a place of special significance by applying for a federal designation of the Delta as a National Heritage Area (NHA). The NHA designation is granted by the U.S. Congress to places where natural, cultural, historic, and recreational resources combine to form a distinctive landscape and tell a nationally important story about the country and its experience.

The DPC also recommends strategies to support increased investment in agriculture, recreation, tourism, and other resilient land uses in the Delta. These strategies are derived from the ESP (DPC 2012b). Established in 2009, the Delta Conservancy is responsible for implementing ecosystem restoration projects protecting and preserving agriculture and working landscapes; increasing recreation and tourism opportunities; promoting legacy communities and economic vitality; and protecting, conserving, and restoring the region's physical, agricultural, cultural, historical, and living resources (Public Resources Code section 32322). Careful coordination between the DPC and Delta Conservancy can maximize the impact of both agencies' economic development activities.

Protecting the Delta as an Evolving Place Is Inherent in the Coequal Goals

Protecting the Delta as an evolving place is inherent in the coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. This is partly because attaining these two goals will necessitate a growing awareness among Californians of the Delta and its values, including its agriculture, recreation, natural resources, and unique culture. It is also because Delta residents benefit from the levees that help convey fresh water through the Delta; enjoy the wildlife, fish, and recreation that the Delta ecosystem produces; and work for its water management agencies and facilities. Changes required to provide a more reliable water supply or restore the ecosystem will influence the kind of place the Delta becomes, especially if structures to improve conveyance or areas of restored habitat significantly alter the Delta's familiar farming landscape. At the same time, the needs to protect the Delta's land uses and people will shape and constrain decisions about water supplies and ecosystem restoration, including allocation of water supplies, flow and salinity objectives, levee priorities, and how impacts to communities and land uses are mitigated.

Water for agricultural, municipal, and industrial uses is a key to the Delta as a place. Delta communities are the most dependent of all Californians on Delta water supplies, which support its residents, businesses, and farms. They, like other Californians, can often do more to use water more efficiently and to develop alternative supplies through recycling, conjunctive use of groundwater, or participation in regional water supply projects. Because the communities and economy of the Delta require water of reliable quality as well as amount, updates to the Bay-Delta Water Quality Control Plan have special influence on the region. The Delta is also influenced by other Central Valley water quality plans because they protect the quality of water for Delta consumers, farmers, and recreationists and the costs Delta residents and businesses pay to meet clean water standards.

A healthy ecosystem is also important to the Delta's communities. Residents find joy and relaxation in outdoor recreation and the connection with nature that the Delta ecosystem provides. Visitors drawn to its scenery, waterways, fish, and wildlife support tourism businesses. Protecting the ecosystem maintains these benefits and restoring it can expand them, especially when it can be accomplished in ways that enhance the Delta's working landscape. Coordinating restoration with planning for flood control can help control costs for levee improvement and management, draw on multiple sources of funds for multipurpose flood control investments, and provide alternate uses for areas that cannot be protected cost effectively. Restoring marshes, riverbanks, and riparian areas will alter how some land is used, but the impacts of these changes on the Delta's unique values can be managed through cooperation, careful design to lessen or avoid adverse effects, or reasonable mitigation of unavoidable impacts.

The Delta as a Place

The California Delta is a unique place distinguished by its geography, legacy communities, a rural and agricultural setting, vibrant natural resources, and a mix of economic activities. This section describes the features that make the Delta unique. Its 839,640 acres of land, sometimes centered on a wide river but laced with a network of narrow channels and sloughs, stretch to the horizon, bounded only by the levees that were built to drain the Delta's marshes and floodprone riversides. The Legislature has found that the Delta's uniqueness is particularly characterized by its hundreds of miles of meandering waterways and the many islands adjacent to them, and has described the Delta's highly productive agriculture, recreational assets, fisheries, and wildlife as invaluable resources (Water Code section 12981(b)). These natural assets, including the ecosystem and water resources as described in Chapters 3, 4, and 6, are among the Delta's important values.

The Delta is composed of three areas recognized in California law. The Primary Zone is the largest and includes 490,050 acres at the heart of the Delta (Public Resources Code section 29728). It is primarily rural farmland, but also includes several small towns established in the nineteenth and twentieth centuries. The Secondary Zone includes 247,320 acres surrounding the Primary Zone (Public Resources Code section 29731). It also includes farmland, but is increasingly dominated by the region's cities and suburbs. Suisun Marsh lies northwest of the Primary Zone, encompassing 106,570 acres (Public Resources Code section 29101) primarily of managed wetland. The Suisun Marsh overlaps the boundary of the Delta by about 4,300 acres (see Figure 5-1).

The Legislature has declared that the Delta is a natural resource of statewide, national, and international significance, and that the cities, towns, and settlements within the Delta are of significant historical, cultural, and economic value (Public Resources Code sections 29701 and 29708). However, not all Delta users, visitors, or residents recognize or appreciate the Delta's values. In a recent survey, 78 percent of Californians said they had not heard of or did not know about the Delta (Probolsky Research 2012). A survey in 2007 found that nearly half of Stockton residents had only a vague idea—or none at all—that they lived in or near the Delta (*Stockton Record* 2012).

This lack of a clearly recognized, widely communicated identity for the Delta is described as the lack of a "brand." Delivering a coordinated message about the Delta and its resources is difficult because responsibilities for the Delta are divided among so many agencies. Many visitors and even some residents of Delta cities and suburbs are unfamiliar with the region beyond their travel route or community, or know it only in name from news media reports about conflicts over its water and natural resources. To some, the Delta's flat agricultural landscape is dull and monotonous, and its resources are "out of sight and out of mind." Access into the Delta by first-time visitors can be difficult because of its winding roads and lack of amenities that signify a special region; simplify wayfinding; educate travelers about an area's history, culture, and natural resources; or encourage public access and recreation.

Delta Primary and Secondary Zones and Suisun Marsh

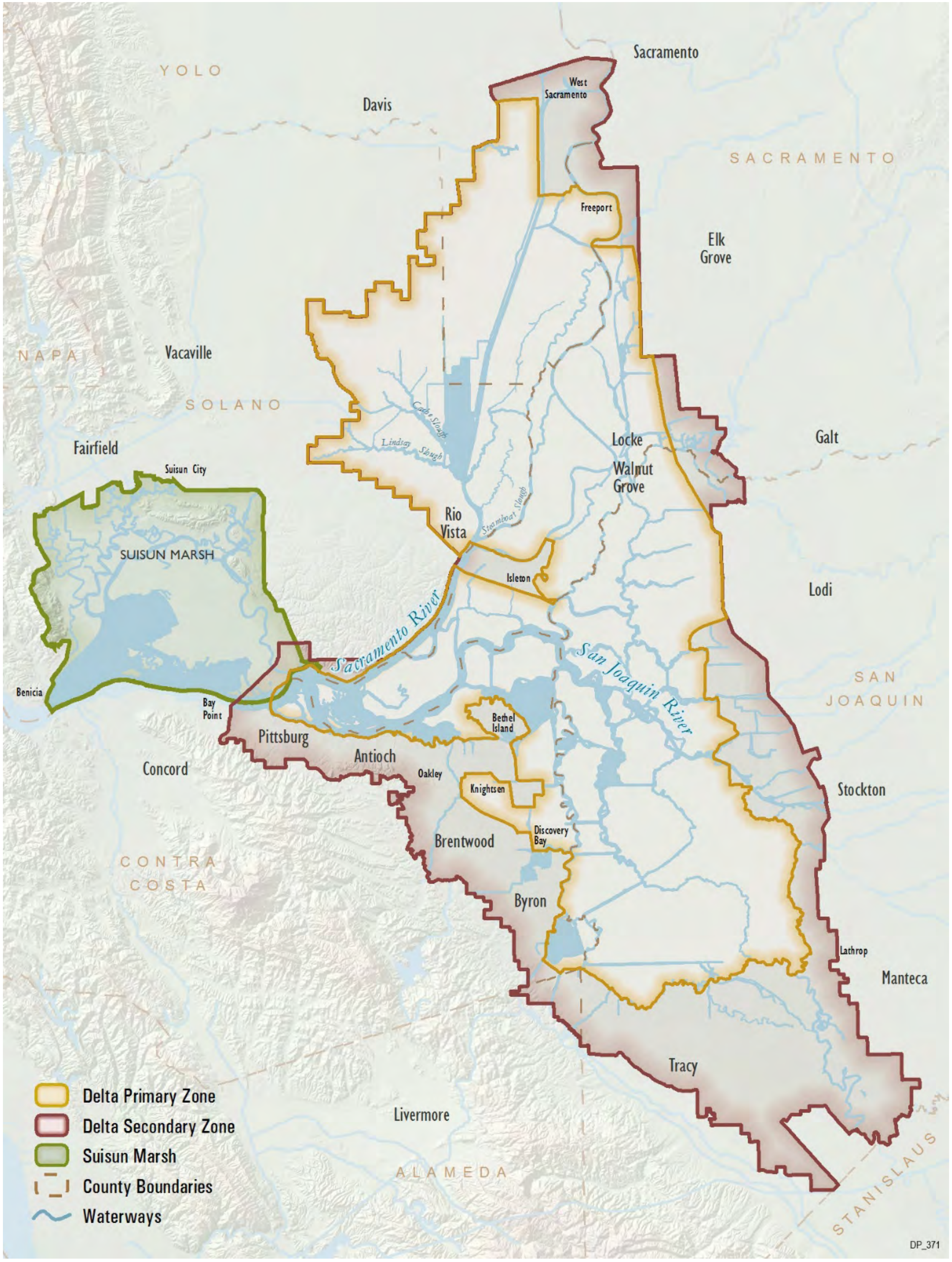

Figure 5-1

The Delta's People

About 570,000 people reside in the Delta, according to the 2010 Census. Ninety-eight percent of them live in the Delta's Secondary Zone, with the remainder in the Primary Zone. Prior to the recent recession, the population of the Delta's Secondary Zone had been growing rapidly, increasing almost 56 percent since the 1990 Census, a rate twice as fast as the state as a whole. Much of that increase occurred in new communities in previously unincorporated county areas, such as Discovery Bay; rapidly growing towns and communities such as Brentwood and Oakley on State Route 4; and cities such as Sacramento, West Sacramento, Stockton, and Lathrop. The age and household composition of the Delta's population is similar to California as a whole, but with slightly younger and larger families. About half the Delta's population is between the ages of 21 and 54, and about 29 percent are younger than 18 years old (DPC 2012b).

In contrast, the population of the Primary Zone has been essentially unchanged over those 20 years. The Primary Zone is also composed primarily of older people without children, living in smaller households.

Today, most Delta residents describe themselves as white or Hispanic, with the next largest groups being Asian, other races, and African-American or black. About one-third describe themselves as Hispanic. This diverse population reflects the many United States regions and foreign lands from which settlers emigrated to the Delta, including Mexico, China, Japan, Portugal, the Philippines, and other countries. These origins are reflected in communities and neighborhoods like Locke, an early twentieth century town built primarily by Chinese farmworkers. Cultural events honor many ethnic traditions in the Delta, including Chinese and Cambodian New Years, Portuguese festas, Greek holidays, Indian Diwali celebrations, Filipino fiestas, Cinco de Mayo events, and Juneteenth commemorations. Other festivals feature Delta agriculture, such as the Courtland Pear Fair and the Stockton Asparagus Festival (California State Parks 2011).

The Delta's Communities

The region's urban communities include the cities of Sacramento, West Sacramento, Stockton, Lathrop, Manteca, Tracy, Oakley, Brentwood, Antioch, Pittsburg, Benicia, Fairfield, Suisun City, Rio Vista, and Isleton, and the unincorporated communities of Freeport, Mountain House, Byron, Discovery Bay, Bethel Island, and Knightsen. They are located entirely or partially in the Delta's Secondary Zone or in the secondary management area of Suisun Marsh. Unincorporated communities in the Primary Zone include Clarksburg, Courtland, Hood, Locke, Walnut Grove, and Ryde. Appendix B includes maps of these unincorporated communities.

The general plans of Delta cities and counties describe where development of these communities may occur. These plans or actions by the local area formation commissions describe "spheres of influence" (SOIs) for each jurisdiction and often identify an urban limit line beyond which intense development cannot occur without amendment of the plan. About 26,000 acres of the Delta within these SOIs are expected to undergo urbanization (DPC 2012b) (see Figure 5-2). To encourage the location of new development within these SOIs rather than in rural areas, Chapter 7 policies exempt development in these areas from policies to increase flood protection standards. The Delta Plan includes no policies or recommendations to control land use or density in these communities.

Among the Delta's unincorporated communities, Bethel Island warrants a special note because of its flood risks, the development planned there, and its lack of public services. Its developed area occupies part of the 3,500-acre island, most of which is planned for rural agricultural or visitor-serving commercial uses. About 2,100 people reside on the island in about 1,300 residences concentrated on the island's south central shoreline, four mobile home parks, or 13 commercial marinas. Approximately 15 miles of levees surround the island, which is below sea level, limiting the drainage of floodwaters in the event of a levee breach.

A single road, Bethel Island Road, links the island to the mainland at the city of Oakley, complicating emergency response or evacuation in the event of flooding. Although the entire island is included in the urban limit line that Contra County's voters approved in 2006, development on the island clusters around Delta Coves, a 495-unit water-oriented residential development that was permitted in 1973, but that still remains unfinished, in part because of the bankruptcy of its developer. Other development includes mobile home parks and retail areas. Rural uses include single-family homes along the island's shoreline, marinas, resorts, a golf course, rural residential uses, and farmland. Contra Costa County's General Plan seeks to preserve and enhance the rural quality of Bethel Island and still allow for planned residential and commercial growth related to water-oriented recreation. The general plan notes that development other than a single home on existing parcels must await resolution of several issues, including improvement of the community's public services, levees, and emergency evacuation routes. Because of its flood risks and its rural character, Bethel Island is not excluded from the Delta Plan policy limiting new urban development. Restrictions on development on Bethel Island are consistent with the Contra Costa County General Plan.

As described in Chapter 2, covered actions subject to the Delta Reform Act do not include plans, programs, or projects within the Delta's Secondary Zone that a metropolitan planning agency has determined are consistent with a sustainable communities strategy adopted under California planning law. These sustainable communities strategies will, in part, accomplish the following:

- Identify the general location of uses, residential densities, and building intensities within the region.
- Identify areas within the region over their 20-plus-year planning period sufficient to house the population of the region.
- Identify areas within the region sufficient to house an 8-year projection of the regional housing need for the region.
- Identify a transportation network to serve the transportation needs of the region.
- Gather and consider information regarding resource areas and farmland in the region.
- Set forth a forecast development pattern, which, when integrated with the transportation network and other transportation measures and policies, will reduce greenhouse gas emissions from automobiles and light trucks. The sustainable community strategy development pattern will need to be based upon "current planning assumptions" that include the information in local general plans and SOI boundaries.

As provided in Water Code section 85212, the Council will cooperate with local and regional planning agencies to provide timely advice about sustainable community strategies and other local and regional plans for consistency with the Delta Plan. This will include reviewing their consistency with the ecosystem restoration needs of the Delta and whether these plans set aside sufficient lands for natural resource protection to meet the Delta's ecosystem needs. Through this coordination, decisions about locating and planning new urban development in the Secondary Zone can be coordinated to meet local communities' housing and other needs, as Water Code section 85022(d)(4) provides, while protecting and enhancing the Delta as an evolving place.

Delta Communities

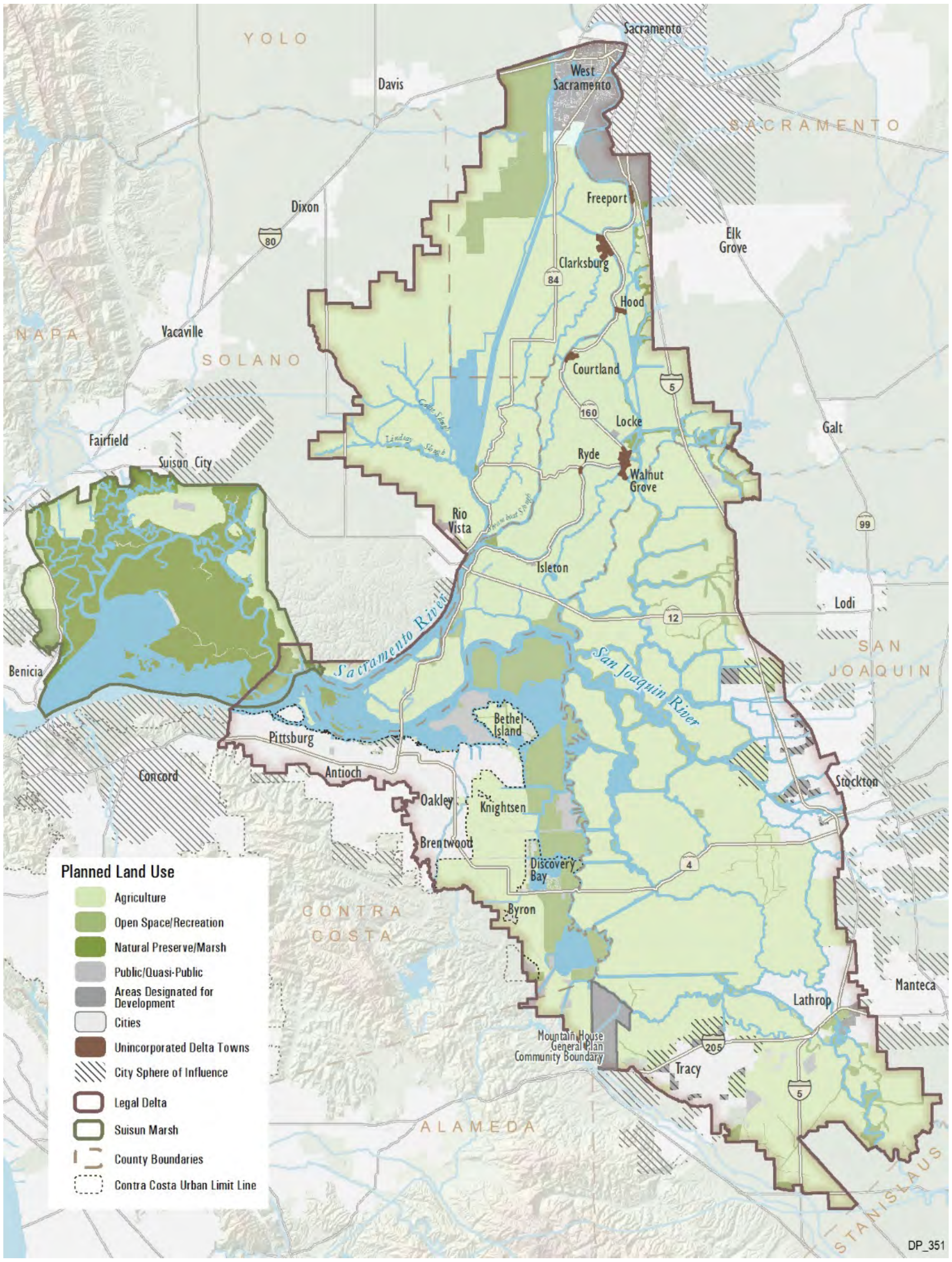

Figure 5-2 The map shows land uses designated by city and county general plans. Within cities' SOIs, the map shows land use designations proposed in city general plans, where available. In cases where cities have not proposed land uses within their SOIs, the map shows land uses designated by county general plans.

Sources: City of Benicia 2003, Contra Costa County 2008, Contra Costa County 2010, City of Fairfield 2008, City of Lathrop 2012, City of Manteca 2012, Mountain House Community Services District 2008, City of Rio Vista 2001, SACOG 2009, City of Sacramento 2008, Sacramento County 2011, Sacramento County 2012, Sacramento County 2013, San Joaquin County 2008a, San Joaquin County 2008b, Solano County 2008a, Solano County 2008b, City of Stockton 2011a, City of Stockton 2011b, City of Suisun City 2011, City of Tracy 2011a, City of Tracy 2011b, City of West Sacramento 2010, Yolo County 2010a, Yolo County 2010b.

The Delta's Legacy Communities

Bethel Island, Clarksburg, Courtland, Freeport, Hood, Isleton, Knightsen, Rio Vista, Ryde, Locke, and Walnut Grove are the Delta's legacy communities (Public Resources Code section 32301(f)). They are the residential, commercial, processing, and retail centers of the Delta, and resonate with its history and culture. Each community has its own character. Bethel Island is a recreation destination. Clarksburg and Courtland are centers for wine and pear production. Freeport and Hood were transportation centers, with river landings and rail spurs to move goods. Locke and Walnut Grove had large Asian populations who worked at packing sheds and surrounding local farms. Ryde is known for its landmark hotel, and Isleton is known for festivals and visitor-serving businesses. Rio Vista is the largest community, and Knightsen is a small community known for several nearby horse ranches. All legacy communities except Freeport, Isleton, and Bethel Island are in the Primary Zone. Rio Vista is partly in the Primary Zone and partly outside the Delta. The DPC ESP highlights the rich cultural histories of these distinctive communities and notes the importance of enhancing their legacy themes and creating better awareness of them. It highlights planning to strengthen these communities by building on the agricultural uses that surround them. It also recommends enhancing the Delta's recreation and tourism opportunities by improving these towns' lodging, entertainment, and retail options; encouraging agritourism; restoring historic buildings; and promoting context-sensitive infill development, including housing for the Delta's workforce.

Flood risks in these communities are higher than in the Delta's cities, as noted in Chapter 7, and they are too small to be capable of financing major levee improvements without significant assistance. According to the ESP, opportunities for residential or visitor-serving recreation developments in these communities may be impaired if flood risks are too high or development regulations are unpredictable or too burdensome. Although improvements to these communities' historic structures are exempt from Federal Emergency Management Agency (FEMA) floodproofing standards (FEMA 2008), flood risks, floodproofing standards for new development, and flood insurance costs can be barriers to business investment or development.

THE LEGACY OF THE DELTA'S NATIVE CALIFORNIA INDIANS

People have occupied the Delta for thousands of years. Early people gathered wild plants, including seeds, roots, greens, mushrooms, and nuts; hunted for rabbits, waterfowl, tule elk, or antelope; and speared or netted salmon, sturgeon, and other fish. Acorn processing allowed populations to grow. Permanent villages of 100 or more residents were established on sand mounds along major waterways, at the margins of tule marshes, and on the shores of Suisun Bay. Sandy uplands on Delta islands held smaller settlements. Boats of tule reeds were used to travel Delta waterways. Trade with neighbors brought obsidian and other tool stones, shell or bone ornaments, charm stones, and other goods from the coast and Sierra.

Four main groups resided in the Delta: Nisenan on the north, Miwok on the east, Yokuts in the south Delta and Contra Costa shoreline, and Patwin around Suisun Marsh and Putah Creek. Their presence is still acknowledged in place names (for example, Yolo, Suisun, and Mokelumne) and in artifacts such as stone pestles and bedrock mortars for grinding seeds and nuts; twined basketry of rushes and other plants; ancient habitations demarked by charcoal, shells, or other refuse; and cemeteries where loved ones were carefully buried, sometimes with ochre, beads, and other objects, or cremated. Today their descendants sustain a contemporary native California Indian community in the Delta.

*Sources: Beals 1933, Bennyhoff and Fredrickson 1969, Fredrickson 1974, Johnson 1978, Kroeber 1925, Kroeber 1932, Levy 1978, Moratto 1984, University of California Archaeological Survey 1956, Wallace 1978,
Wilson and Towne 1978*

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Climate Change

Historical, cultural, and economic resources of the Delta are subject to the impacts of climate change. An increase in sea level of up to 55 inches is projected to occur by 2100. Along with increased flood risk associated with rising sea levels and changes in runoff timing and intensity, levees, highways, and other infrastructure that support the Delta's communities and economy will be threatened. In addition, land use planning is complicated by the prospect of rising sea levels and increased flooding that may accompany climate change. Rising water levels and more severe flooding will increase hazards to land uses and developments, and confound efforts to identify safe locations for new homes and businesses.

Impacts on agriculture, such as decreasing revenues, are also likely if Delta water supplies increase in salinity (Lund et al. 2007) and water demand increases. Impacts on agriculture from warming temperatures could reduce yields and increase vulnerability to weeds and pests (California Resources Agency 2008), as well as increase soil subsidence rates through increased rates of organic matter oxidation. In addition, Delta recreation and tourism could be affected by changes in Delta fisheries.

Land Use Planning in the Delta and Suisun Marsh

The land uses in the Delta are the result of myriad decisions made by residents, businesses, investors, and others since its settlement. These decisions are shaped today by local and State agencies that are responsible for planning or regulating land use or development. Primary authority for land use planning rests with the Delta's twelve cities and five counties, which are required to adopt comprehensive long-range general plans to guide development. In addition, the Legislature has authorized three State agencies to oversee land use planning by local governments or directly regulate land use actions in the Delta and the Suisun Marsh: the Council, the DPC, and the San Francisco Bay Conservation and Development Commission (BCDC). The Council and the DPC have concurrent jurisdiction in the Delta's Primary Zone, while the Council and BCDC have concurrent jurisdiction in the Suisun Marsh. The DPC and BCDC must ensure that local land use planning is consistent with their own laws and plans, and must also certify that any covered actions that they carry out or approve, such as updating their plans, are consistent with the Delta Plan (see Table 5-1).

The Council's Role

The Legislature has declared that existing developed uses and future developments that are carefully planned and developed consistent with Delta Reform Act policies are essential to Californians' economic and social well-being, especially those who live or work in the Delta. The Delta Reform Act includes six goals for managing land use (Water Code section 85022(d)):

> (1) *Protect, maintain, enhance, and, where feasible, restore the overall quality of the Delta environment and its natural and artificial resources.*
>
> (2) *Ensure the utilization and conservation of Delta resources, taking into account the social and economic needs of the people of the state.*

State Agencies with Land Use Jurisdiction in the Delta

TABLE 5-1

State Agency	Law	Plan
Delta Stewardship Council	Sacramento-San Joaquin Delta Reform Act of 2009	Delta Plan
Delta Protection Council	Delta Protection Act of 1992	Delta Land Use and Resource Management Plan for the Primary Zone of the Delta
San Francisco Bay Conservation and Development Commission	McAteer-Petris Act of 1965, Suisun Marsh Preservation Act of 1977	San Francisco Bay Plan, Suisun Marsh Protection Plan

> *(3) Maximize public access to Delta resources and maximize public recreational opportunities in the Delta consistent with sound resources conservation principles and constitutionally protected rights of private property owners.*
>
> *(4) Encourage state and local initiatives and cooperation in preparing procedures to implement coordinated planning and development for mutually beneficial uses, including educational uses, in the Delta.*
>
> *(5) Develop new or improved aquatic and terrestrial habitat and protect existing habitats to advance the goal of restoring and enhancing the Delta ecosystem.*
>
> *(6) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.*

Goals 2, 3, and 4 are addressed in this chapter.

In addition, Water Code section 85305(a) provides, in part:

> *The Delta Plan shall attempt to reduce risks to people, property, and state interests in the Delta by promoting…appropriate land uses.*

Water Code section 85022(a) directs "state and local land use actions identified as covered actions pursuant to section 85057.5 be consistent with the Delta Plan" and that the section's "findings, policies, and goals apply to Delta land use planning and development." Thus, the Council's role in reviewing land use actions is to consider the full range of State interests in the Delta, including the economic and social well-being of Californians, environmental protection, use and conservation of resources, public access and recreation, habitat restoration and enhancement, water quality, and flood protection.

The DPC's Role

The DPC *Land Use and Resource Management Plan for the Primary Zone of the Delta* (2010) guides land uses in the Primary Zone. Local government general plans must be consistent with the DPC's land use and resource management plan. Local government land use actions may be appealed to the DPC for review of consistency with the land use and resource management plan. Chapter 2 describes the special role that the Delta Reform Act gives to the DPC to review and comment on significant projects or programs, such as ecosystem restoration or flood control projects, under consideration by the Council. The referral of projects to DPC for its review and comment and the membership of the DPC chair on the Council assure that the Delta communities will have a voice concerning actions' effects on existing and planned uses of the Delta.

The DPC's management plan states these goals for land use in the Primary Zone (DPC 2010):

> *Protect the unique character and qualities of the Primary Zone by preserving the cultural heritage, strong agricultural/economic base, unique recreational resources, and biological diversity of the Primary Zone. Direct new non-agriculturally oriented non-farmworker residential development within the existing unincorporated towns (Walnut Grove, Clarksburg, Courtland, Hood, Locke, and Ryde).*
>
> *Encourage a critical mass of farms, agriculturally-related businesses and supporting infrastructure to ensure the economic vitality of agriculture within the Delta.*

DPC's management plan also acknowledges the importance of balancing urban development with the protection of agriculture and other rural lands (DPC 2010):

> *The periphery of the Delta is undergoing rapid urbanization associated with substantial population growth. Current and future population growth increases the demand for developable land, particularly in areas near the Bay area, Stockton, and Sacramento. This demand results in the conversion of open space, primarily agricultural land, to residential and commercial uses. Increasing concern exists regarding the potential for urbanization and projects in the Secondary Zone to impact the Primary Zone.*

Thus, the DPC's role in land use review is primarily to protect agricultural land, recreational uses, and biological diversity in the Delta's Primary Zone from urban development, direct most residential development within existing towns, and ensure the economic vitality of Delta agriculture.

BCDC's Role

The BCDC was established by the McAteer-Petris Act in 1965. The agency prepared the *San Francisco Bay Plan* to guide the conservation of the Bay's natural resources and development of its shoreline. In 1977, BCDC's authority was expanded to protect wildlife use and retain biological diversity of the Suisun Marsh under the Suisun Marsh Preservation Act. With respect to land use, the Suisun Marsh Preservation Act (Public Resources Code section 29003(e) and (f)) calls for:

- Development and implementation of plans and policies to protect the marsh from degradation by excessive human use
- Definition and establishment of a buffer area consisting of upland areas that have high wildlife values themselves and also contribute to the integrity and continued wildlife use of the wetlands within the marsh

BCDC's *Suisun Marsh Protection Plan* (SMPP) guides land use and development in the Marsh (BCDC 1976). The SMPP designates an 89,000-acre primary management area of waterways, including Suisun, Honker, and Grizzly bays, tidal marshes, and managed wetlands; and a buffer zone of upland grasslands and agricultural land composing a 22,500-acre secondary management area. Both the Bay Plan and the SMPP apply to Suisun Marsh, and the SMPP controls if there is a conflict. BCDC also is the federally designated State coastal management agency for the San Francisco Bay segment of the California coastal zone. The federal Coastal Zone Management Act (CZMA) empowers BCDC to ensure that federal projects and activities are consistent with BCDC's laws and policies. A marsh development permit from BCDC is required to place fill, dredge, construct a structure, substantially change land use, subdivide property, or grade land in the wetlands and waterways of the Suisun Marsh.

BCDC retains planning and permitting authority in the primary management area of the Marsh, but shares authority in the secondary management area with local government agencies and special districts. The Suisun Marsh Preservation Act authorizes BCDC to delegate authority to issue marsh development permits to local agencies and special districts with jurisdiction in the marsh after BCDC has certified that their components of the Suisun Marsh Local Protection Program (LPP) are consistent with the Suisun Marsh Preservation Act and the SMPP. BCDC first certified all the components of the LPP in the early 1980s. LPP components can be amended only after BCDC holds a public hearing and votes for recertification. Permits granted by local governments for projects in the secondary management area under the authority of their LPP component may be appealed to BCDC.

Thus, BCDC's role in the Suisun Marsh is to protect the unique natural resources of the Suisun Marsh from the potential adverse effects of development by directly regulating land use in the primary management area of the marsh and working with local government to regulate land use in the secondary management area.

Other Agency Jurisdictions

Land use and development in the Delta are also affected by other State and federal agencies. The State Lands Commission has jurisdiction over hundreds of miles of waterways in the Delta, and issues leases for in-stream structures and uses. The Central Valley Flood Protection Board issues permits to encroach in floodways and State flood management facilities. The State and regional water quality control boards control discharges from development to public waters. The California Department of Fish and Wildlife (DFW) regulates projects that affect waterways or habitats of State-listed endangered or rare species.

Among federal agencies, FEMA has a significant effect in the region by establishing floodproofing standards for new development in communities that participate in its National Flood Insurance Program. The U.S. Army Corps of Engineers oversees the filling of public waters and wetlands. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service regulate development that affects essential fish habitat or federally listed endangered or rare species. Some Delta landowners see these complex rules as a barrier to the development and use of private land. As described in Chapter 2, the Delta Plan Interagency Implementation Committee will improve coordination among regulatory agencies to ease some of these barriers.

Minimizing Land Use Conflicts

Poorly sited or designed development can also encourage additional people to place their lives and property at risk as well as restrict ecosystem restoration opportunities (see Chapter 4 and Chapter 7). Many uses are already in hazardous locations. For example, about 116,000 residential structures are located in the 100-year floodplain of the Delta, mostly near Sacramento, West Sacramento, and Stockton. Almost 8,000 residences are below mean higher high water (DWR 2008). Land use planning is complicated by the prospect of rising sea levels and increased flooding that may accompany climate changes. Some necessary water facilities, ecosystem restoration projects, or flood management facilities may need to be located on farmlands or in other locations that are inconsistent with local land use plans. State and federal agency projects are not required to secure approvals from local governments or the DPC, but nevertheless should avoid conflicts with existing and planned land uses when feasible. These projects can alter scenic views, make noise, create conflicts with adjoining land uses, generate traffic, or disrupt transportation routes if not planned carefully. Fully considering local resident views and local government positions can minimize misunderstandings, reduce avoidable conflicts, and build trust and cooperation.

The Delta's Economy

This section provides an overview of the primary sectors that make up the Delta economy. The Delta's economy is primarily urban and service oriented. The Delta is a diverse, growing, and economically integrated region that in many respects is outperforming the state as a whole. Transportation, warehousing, and utilities are important sectors. Construction, housing, and real estate are also important, but have declined with the recent recession. Retail, education, health care, and accommodations are the top employment sectors. The Primary Zone is less diverse, and depends on agriculture and, to a lesser extent, recreation and tourism. Stockton, Sacramento, and other nearby urban areas provide employment for professionals who commute from the Primary Zone, and less-skilled workers commute into the Primary Zone to jobs in agriculture and food processing.

Agriculture and the Delta's Economy

The total value of Delta crops was approximately $702 million in 2009. Truck and vineyard crops account for 54 percent of crop revenues on 18 percent of acreage. The top five Delta crops in terms of value were (1) processing tomatoes, (2) wine grapes, (3) corn, (4) alfalfa, and

(5) asparagus. The highest per-acre values in the Delta come from truck crops mainly situated in the southern Delta and deciduous crops principally located in the northern Delta. Table 5-2 summarizes top crops by gross value and acreage.

Top Five Crops in the Delta

TABLE 5-2

Position (2009)	By Gross Value	By Acres Grown
1	Tomatoes	Corn
2	Wine Grapes	Alfalfa
3	Corn	Tomatoes
4	Alfalfa	Wheat
5	Asparagus	Wine Grapes

Source: DPC 2012b

When related value-added manufacturing such as wineries, canneries, and dairy products are included, the total economic impact of Delta agriculture is 13,179 jobs, $1.059 billion in value added, and nearly $2.647 billion in economic output in the five Delta counties. Including value-added manufacturing, the statewide impact of Delta agriculture is 25,125 jobs, $2.135 billion in value added, and $5.372 billion in economic output (DPC 2012b).

See the Agriculture in the Delta section for a more detailed description of agriculture and its contribution to the Delta's way of life and economy.

The Delta's Recreation and Tourism Economy

Recreation and tourism are important contributors to the Delta's economy. DPC's ESP estimates that Delta recreation and tourism support 3,000 jobs with $100 million in wages in the Delta counties; $312 million in direct expenditures in the Delta by anglers, hunters, boaters, picnickers, campers, hikers, bicyclists, visitors driving for pleasure, and others who recreate in parks, wildlife areas, trails, or roadways; and a total of $175 million in value added to the regional economy. Statewide, Delta recreation and tourism support 5,200 jobs and contribute $348 million in value added.

Despite these significant contributions, the Delta's recreation and tourism economy has been relatively flat since the 1990s. The recreation and tourism sectors suffer from limited recognition and understanding of the Delta, and the lack of an overall marketing strategy for the region. Brannan Island State Recreation Area, the best improved State park, is scheduled to close due to budget constraints. Many other public lands lack facilities for visitors. Motor boat registrations have declined in the region. Participation in fishing and hunting has declined also. Private-sector recreation and tourism businesses are stagnant, with employment unchanged over 2 decades and little investment in new facilities. Inadequate levees leave key visitor attractions, including the legacy communities, at risk, as described in Chapter 7. Flood risks, flood insurance, and difficulties in designing attractive but floodproof visitor facilities hinder new investment in recreation and tourism businesses.

Other Contributors to the Delta Economy

The Delta's infrastructure not only supports its residents and businesses, but also includes facilities that transport people and products through the Delta from the Sierra on the east to the Bay Area on the west, or from the Sacramento Valley on the north to the San Joaquin Valley on the south. The Delta's economy benefits from the surface transportation, utilities, and other infrastructure that crisscross the Delta to serve local needs, provide access to regional urban markets, and, in turn, link the Delta's economy to national and global markets.

The Delta's most recognizable infrastructure components are its levees, which are described in Chapter 7. Key transportation corridors include Interstates 80, 5, and 205; State Routes 4, 12, and 160; and railroads operated by Union Pacific, Burlington Northern Santa Fe, Amtrak, and the Altamont Commuter Express. County roads are important for transporting crops to market and for local circulation.

The ports at Stockton and West Sacramento are served by deep water shipping channels that the U.S. Army Corps of Engineers maintains along the San Joaquin and Sacramento rivers, and the Sacramento Deep Water Ship Channel. These ports connect to San Francisco Bay and ultimately to the Pacific Ocean, providing a valuable asset to Delta communities. Rice and other crops grown in the Central Valley and other products are exported across their docks, and fertilizer and other bulk commodities are imported. The Maritime Highway Corridor is a recent initiative to expand maritime traffic between the Delta ports and the Port of Oakland, in part to reduce truck travel and its air quality impacts. Areas for water-dependent industries are located in Collinsville, Rio Vista, Pittsburg, and Antioch, where they benefit from the Delta's abundant and high-quality water.

Other infrastructure in the Delta includes water, drainage, and wastewater treatment facilities. Stockton and Sacramento draw drinking water at least partly from the Delta and discharge wastewater there. The Delta is the site of forebays, pumps, and water control structures of the Central Valley Project and State Water Project, as described in Chapter 3. Aqueducts and other facilities serving the East Bay Municipal Utility District, the Contra Costa Water District, and other areas are located in the Delta. Natural gas wells in the Delta fuel power plants and other energy uses. Wind turbines and other renewable power sources also are located in the Delta. Electric transmission lines and fuel pipelines cross the Delta to carry energy to energy users. Communications towers support broadcasting and telecommunications. These facilities need to be planned carefully to avoid conflicts with water supply, ecosystem restoration, or flood management facilities, and existing and planned land uses.

Delta Investment Fund

In 2009, the Legislature established a Delta Investment Fund in the State Treasury (Public Resources Code section 29778.5). DPC's ESP recommends forming a regional agency to manage the fund, and to implement and facilitate economic development efforts, either through expansion of the DPC's authority or creation of a joint powers authority composed of local governments.

Agriculture in the Delta

Agriculture is among the qualities that define the Delta as a place. This section provides additional detail about the role of agriculture and discusses issues such as subsidence and water quality that must be considered in policy making. The Delta's initial reclamation created farmland, and ongoing maintenance of its levees and water controls allows for continued farming in the region. Agriculture dominates the Delta landscape, as shown on Figure 5-3, and provides the setting for Delta residents' communities, homes, and job sites. Agriculture benefits from the Delta's productive soils, special climate, and abundant water. Delta farms provide a local source of nutritious food and forage for nearby dairies. Farming, food processing, and related industries contribute significantly to the economy, particularly in the Delta's Primary Zone, where they predominate economic output, employment, and value-added activities. Characteristic local crops, such as pears, asparagus, and dried beans, are celebrated at annual festivals and county fairs.

Agriculture in the Delta depends on high-quality farmland. Prime farmlands with the best soils comprise about 400,600 acres, close to 85 percent of all farmland in the Delta. Another 101,760 acres are unique farmland, farmland of statewide or local importance, or farmland of potential local importance (DOC 2009). Because of the fertile peat soils and the moderating marine influence, Delta agriculture's per-acre yields are almost 50 percent higher than the state's average (Trott 2007). As described in Chapters 3 and 4, reliable, abundant fresh water is also an essential contributor to Delta agriculture.

Agricultural Land Use in the Delta

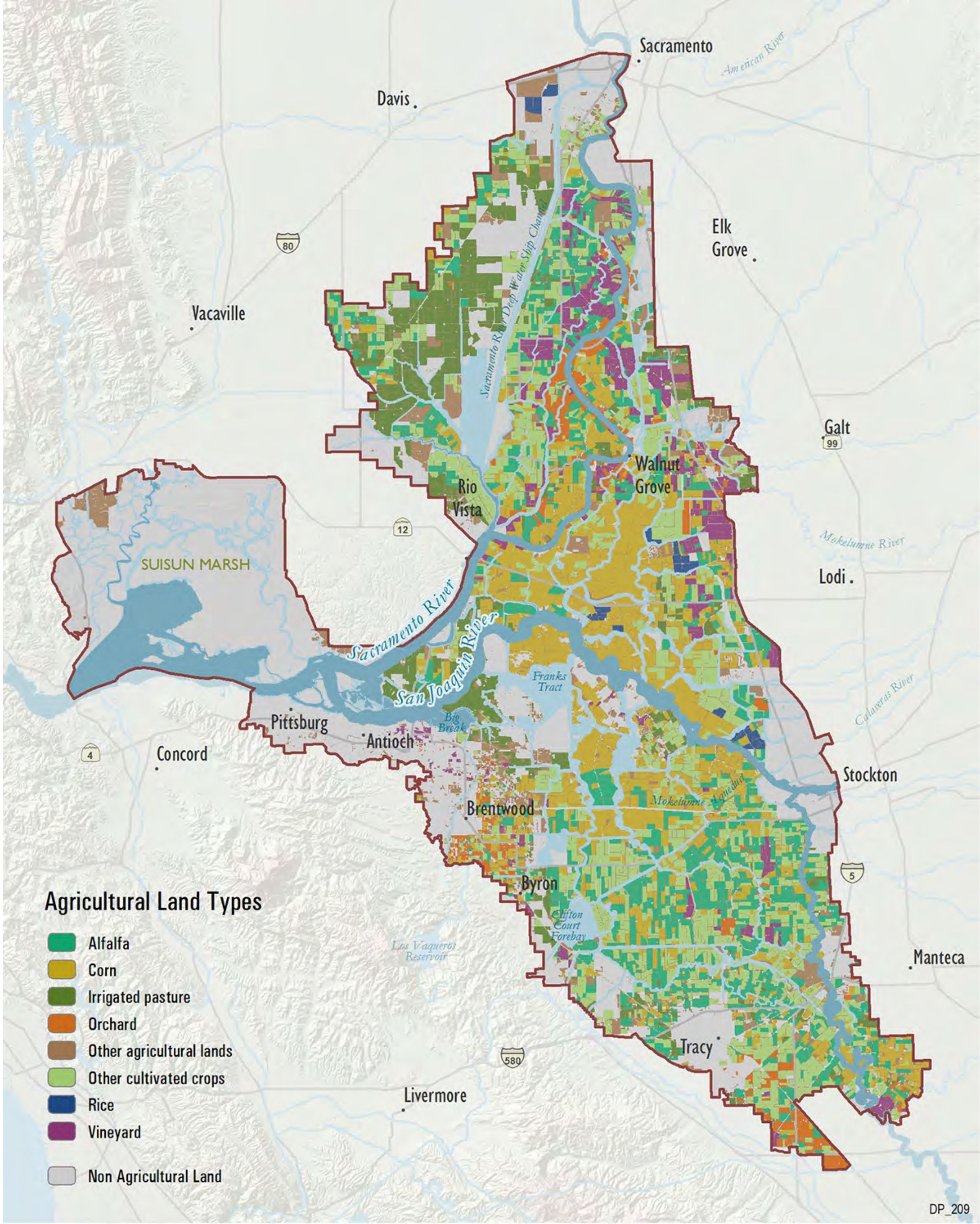

Figure 5-3 *Source: DOC 2008*

Field crops and pasture cover most of the Delta agricultural acreage. In 2010, about one-fourth of farmland in the Delta was corn, much of which is harvested as silage and used in the dairy industry. Alfalfa, the second most widely planted crop, covered about 20 percent of the Delta's farmland. Together, these croplands comprise about 10 percent of the irrigated acreage supporting California's dairy industry. Barley, wheat, and oats were planted on about 69,000 acres. About 41,000 acres of irrigated pasture are used by livestock. Truck crops, including processing tomatoes, asparagus, cucumbers, potatoes, pumpkins, and melons, covered nearly 52,500 acres. Almost 31,000 acres support vineyards. Orchards of pears, almonds, walnuts, and cherries grow on about 17,000 acres (DPC 2012b).

The DPC ESP forecasts that high-value crops, including truck, deciduous, and vineyard crops, are likely to increase in coming decades, potentially increasing farm incomes and economic output. Lower value crops, including field and grain crops, are likely to decline. Some traditional Delta crops are losing markets due to changing consumer preferences and competition from other regions. For example, the Bartlett pear market peaked around World War I, when 50 percent of all Bartletts were produced in California, mainly in the Delta. Until 1930, the Delta was also the world's asparagus capital, producing 90 percent of the globe's production (DPC 2011). Today, a mere 7,200 acres of asparagus fields remain. But growth of wine grapes and other crops, and expansion of local crop processing, particularly winemaking, could enhance agriculture's contribution to the Delta's economy (DPC 2012b). Urban development, ecosystem restoration, or flood control facilities that take farmland out of production could hasten the decline of agriculture.

Value is added to Delta crops when they are processed for ease of use or shipment. Examples include food and beverage manufacturing, such as the tomato canneries or sugar processors that were prominent twentieth century Delta businesses. Today's opportunities include winemaking or emerging sectors such as olive pressing. Special local markets that serve consumers in the Delta counties or Bay Area, such as farm-to-school programs or community-supported agriculture, also may provide new markets for some Delta crops. Facilities that improve the region's capacity to aggregate and distribute its crops to these local markets may enhance Delta agriculture (SACOG 2011). Consistent interpretation and application of regulations about food processing and distribution could help local producers and distributors establish facilities (Sumner and Rosen-Molina 2011).

Protecting Productive Farmlands

Although agriculture is the principal land use in the Delta, the total area of agricultural lands (including fallow lands) in the combined Delta and Suisun Marsh area has declined from about 549,420 acres in 1984[1] to 460,450 acres in 2008, and the percentage of agricultural land has decreased from about 65 percent of this combined area in 1984 to about 55 percent in 2008 (DOC 1984, DOC 1988, DOC 1990, DOC 2008). An additional 28,000 acres of farmland may be lost in the near future under current local government general plans. The Delta Plan acknowledges this loss since it focuses growth within existing city boundaries. However, any further loss of farms to urban development is unacceptable. The continued viability of agriculture in the Delta will require the protection of sufficient farmland and fresh water to support commercially viable operations and provide ways for agriculture to coexist with habitat restoration. Policies DP P1 and DP P2 acknowledge the importance of protecting these lands. The DPC and local governments play key roles in the protection of these lands.

The loss of some farmland to urbanization, habitat, and flooding is inevitable, the DPC ESP concludes; but continued shifts to higher-valued crops and value-added activities, as well as planning restoration in appropriate locations, may help compensate if land loss is not too great. As described in Chapter 4, elevations, locations, and other factors are key

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[1] Data for Sacramento and San Joaquin counties were not available in the 1984 DOC report; thus, data for these counties were taken from the 1988 and 1990 reports, respectively.

determinants of the optimal sites for ecosystem restoration. When these restoration areas include farmlands, achieving the coequal goals of restoring the Delta ecosystem and improving water supply reliability may make some loss of productive agricultural lands unavoidable. Some conveyance alternatives could take farmland out of production, too. Improving flood control facilities may also unavoidably affect some farmland.

Subsidence

The reclamation of Delta islands and their cultivation for agriculture initiated a process of land subsidence, mostly due to oxidation of peat soils, but also from wind erosion. Drainage and cultivation dried the saturated peat, reducing its volume by approximately 50 percent. Early cultivation practices also included burning, which further reduced the volume of the soil and altered its structure. Over time, long-term oxidation reduced about 2.6 to 3.3 billion cubic yards of these peaty soils to small particles and gases. As a result, much of the central Delta today is below sea level, with some islands 12 to 15 feet below sea level. Many islands now more closely resemble bowls surrounded by water, with high sides defined by levees and deep, hollowed-out bases. Although subsidence has slowed in some areas, other regions of the Delta continue to lose soil to oxidation and wind erosion at a rate of 5 to 15 tons/acre/year. It is projected that some areas of the Delta could subside an additional 2 to 4 feet by 2050 (Deverel and Leighton 2010), resulting in the loss of up to 350 to 500 million cubic yards of soil at a rate of 5 to 15 tons/acre/year (see Figure 5-4).

Land subsidence impairs Delta agriculture, not only because of soil loss, but also by increasing the difficulty of maintaining drainage systems and levees. As described in Chapter 7, subsidence makes levees less stable and increases flood risks. The costs to recover a flooded island could be great. Some suggest that many islands would cost more to reclaim after flooding than the value of the land for agriculture. In 1998, 4,200 acres of farmland were lost when Liberty Island flooded and was not reclaimed (Reclamation District 2093 2009). Other once-farmed islands that were not reclaimed after flooding include Big Break, Franks Tract, and Mildred Island (Suddeth et al. 2010).

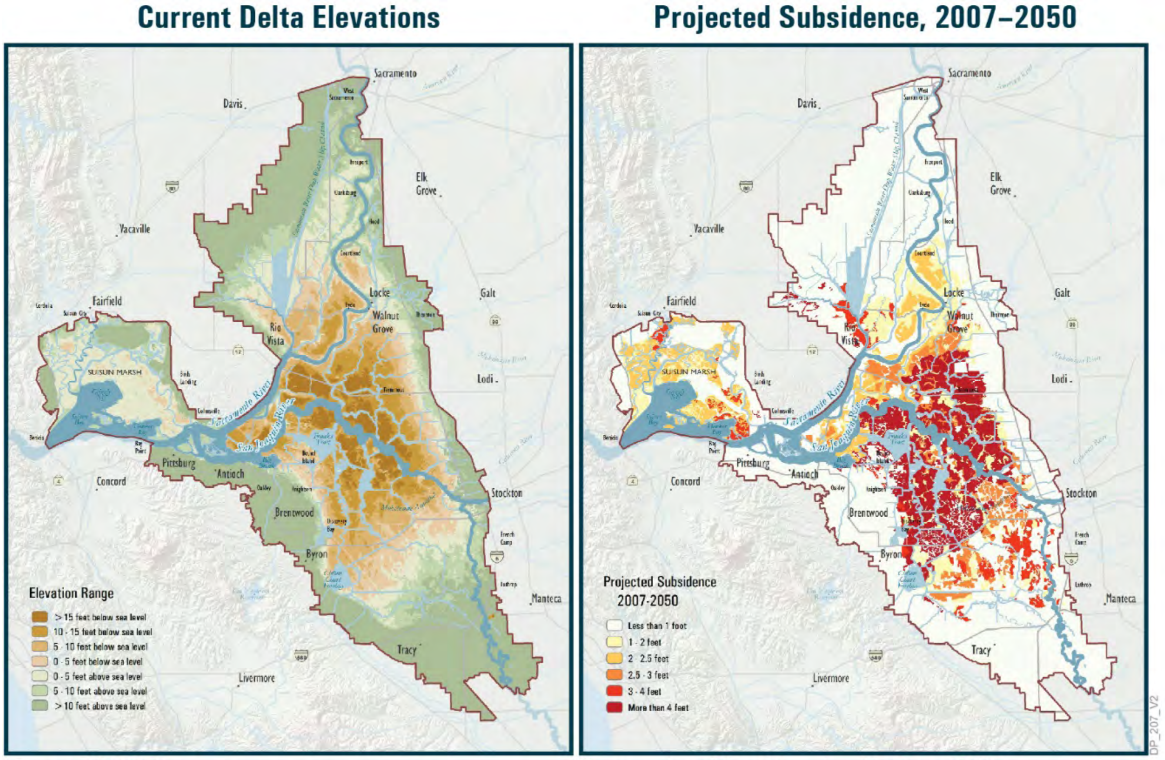
Oxidation of peat soils also liberates vast quantities of carbon dioxide (CO_2), contributing to global warming (Armentano 1980). Oxidation of the Delta's agricultural soils emits about 4.4 to 5.3 million tons of CO_2 annually (Delta Conservancy 2012). For comparison, a typical 500-megawatt coal-fired power plant emits 3 million tons of CO_2 per year.

The potential to retire croplands on deeply subsided islands and manage them to rebuild peat and sequester carbon is sometimes pondered as an alternative to continued farming (Armentano 1980). State and federal agency investigations of alternative land management practices show that soils can be rebuilt, reversing subsidence and sequestering carbon, with some appropriately managed activities, such as tule farming (Miller 2008). Recent actions by the California Air Resources Board, under the California Global Warming Solutions Act of 2006 (Health and Safety Code section 38500 et seq.), provide for the development of a carbon market program, whereby certain activities may be considered acceptable for providing offset credits. Although this program is still in its initial stages, future opportunities may exist for Delta farmers to gain offset credits for growing plants that promote subsidence reversal and sequester carbon.

Agriculture and Water Quality

The DPC's ESP provides scenarios for how potential declines in water quality that could accompany some water conveyance, ecosystem restoration, or water quality actions could affect Delta agriculture. The potential for the agricultural economy to grow in the Delta will depend, in part, on the protection of the Delta's abundant fresh water and the policy response. Chapter 6 contains a detailed discussion of water quality and the Council's strategies for water quality.

Subsidence in the Delta



Source: DWR 2009

Source: adapted from Deverel and Leighton 2010

Figure 5-4 Oxidation of peat soils through natural processes and human activities has caused the land elevation in the Delta to drop. Much of the central Delta is now at or below sea level. Future subsidence has been projected in these areas. As subsidence progresses, levees must be continually maintained, strengthened, and periodically raised to support increasing hydraulic stress.

Wildlife-friendly Agriculture

Agriculture has the potential to coexist with and even enhance restoration of the Delta ecosystem despite the conversion of some farmland to habitat. Techniques that integrate management of agriculture and wildlife habitat, often called "wildlife-friendly agriculture," include crop rotations that include soil-building crops or fallowing; integrated pest management to reduce pesticides; cover crops; the strategic use of permanent crops, such as pasture, to reduce soil disturbance and oxidation; and conservation tillage for field and row crops (Trott 2007). Some native species have adapted to using agricultural lands as habitat in place of tidal marshes, grasslands, and seasonal wetlands. Rice and other flood-irrigated crops support a range of wildlife, especially waterfowl, shorebirds, wading birds, and giant garter snakes. Swainson's hawk, other raptors, and coyote feed on small mammals and ground-nesting birds that inhabit alfalfa fields and other irrigated pastures. Waste grain also provides food for species such as ring-necked pheasant and greater sandhill crane (Trott 2007).

To support Delta agriculture and species recovery, farmers in the Delta are encouraged to implement management practices to maximize habitat values. Some U.S. Department of Agriculture (USDA) programs provide financial incentives for landowners to manage natural areas on their properties, including the Wildlife Habitat Incentives Program, the Environmental Quality Incentives Program, and the Conservation Reserve Program. The DFW, U.S. Fish and Wildlife Service, and Delta Conservancy also can assist landowners who want to enhance wildlife habitat.

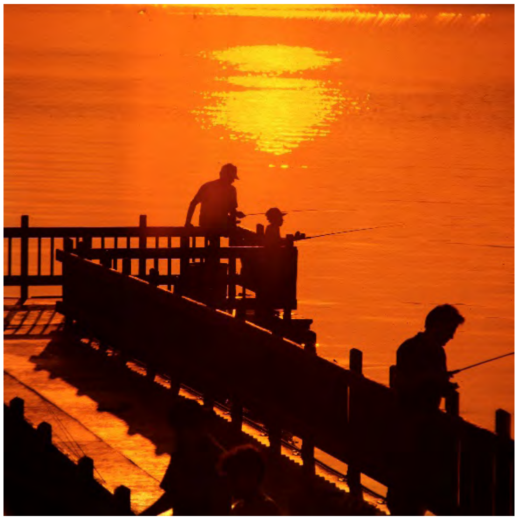
As described in Chapter 4, safe harbor agreements can assure these landowners that the presence of an endangered species on their property will not result in restrictions on activities on their land. Facilitating and creating standard rules for these agreements with Delta landowners may encourage more landowners to participate in conservation programs. Restoring wildlife and fish through wildlife-friendly agriculture can help achieve ecosystem restoration objectives while reducing the loss of farmland to habitat restoration.

Agritourism

Agritourism is another opportunity to add further value to the Delta economy from agricultural activities. Defined as recreational, educational, and other visits to working farms, agritourism is a small but fast-growing source of income for farms in the region and a growing segment of the Delta economy. In the Delta, agritourism destinations may include wineries, on-farm duck clubs, farm stands, and other places. Agritourism was estimated by USDA to generate $4 million in income for farms in the five Delta counties in 2007 (DPC 2012b). For farmers who choose to participate, agritourism can provide additional income, an opportunity to sell farm products directly to consumers, or alternative uses for unproductive lands or buildings. The Discover the Delta Foundation's Delta Discovery Center combines several agritourism functions, including a produce stand, wine sales, and interpretive features that teach people about the Delta's importance (Sumner and Rosen-Molina 2011).

Recreation and Tourism in the Delta

This section provides an overview of recreation and tourism in the Delta. DPC estimates that about 12 million activity days of recreation occur in the Delta annually (DPC 2012b). Recreational users originate from both within and outside the Delta. Visitors value the wide expanses of open land, interlaced waterways, historic towns, and the lifestyle offered by the Delta. The region's mix of land and water offers diverse recreation experiences and facilities, including fishing, boating, birdwatching, other nature activities, hunting, enjoying restaurants, campgrounds, picnic areas, and historic towns and buildings. Recreation also benefits from the Delta's open, agricultural landscape, with its scenic vineyards, orchards, and farmsteads. These are often backed by views of Mt. Diablo or the Montezuma Hills on the horizon, which provide a setting for outdoor photography, a scenic bike ride, or a drive along the Delta's roads. Special events draw visitors to taste local produce and wine, and learn about this unique place. These recreation opportunities are described in more detail in the DPC's ESP and in the Recreation Proposal that California State Parks submitted to the Council and DPC pursuant to Water Code section 85301(c)(1). Figure 5-5 shows the locations of State parks and other protected lands in the Delta. Figure 5-6 shows the variety and distribution of some of these opportunities in the Delta.



State Parks and Other Protected Lands

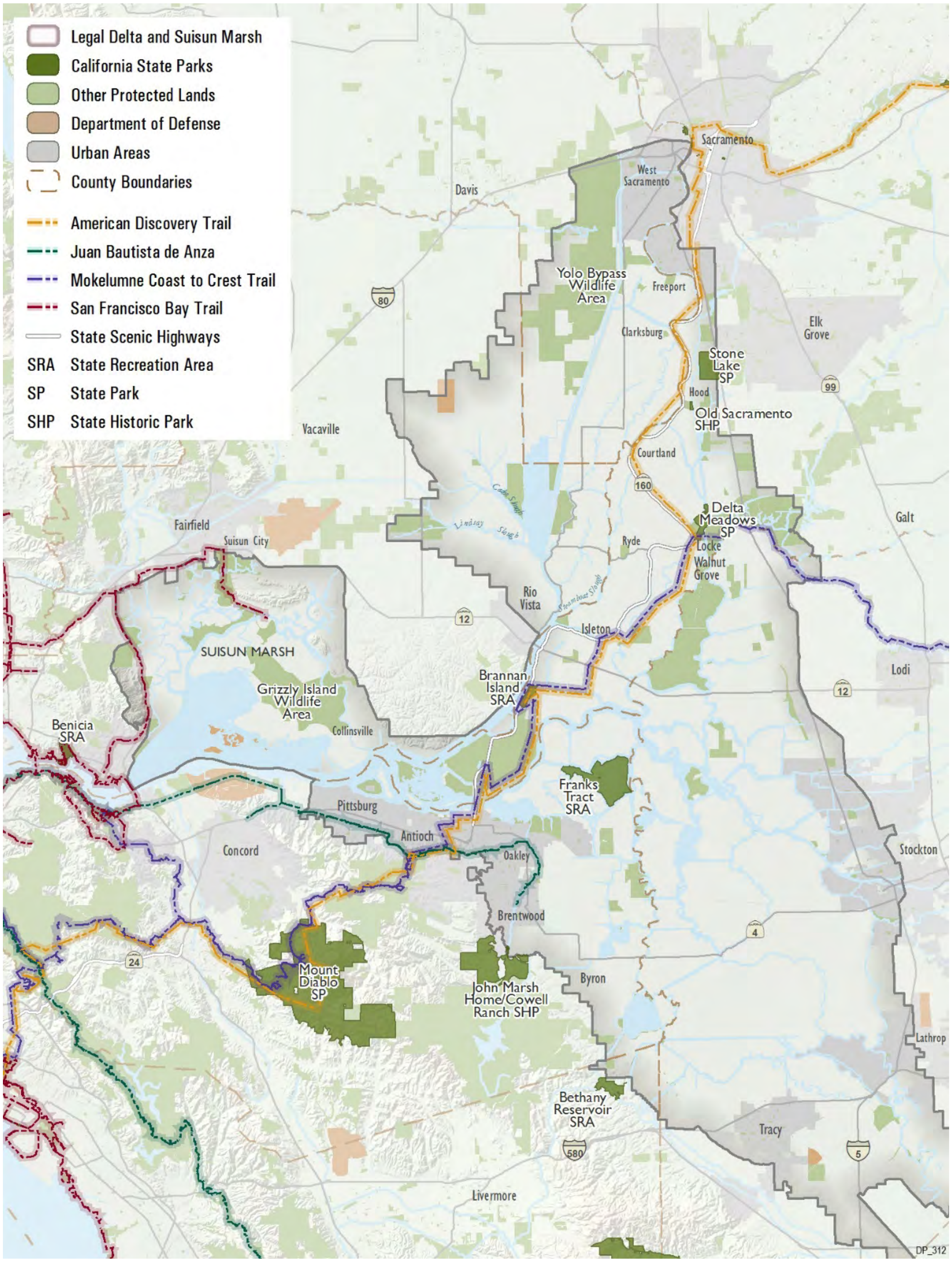


Figure 5-5 *Source: California State Parks 2011*

Major Delta Resources and Recreation

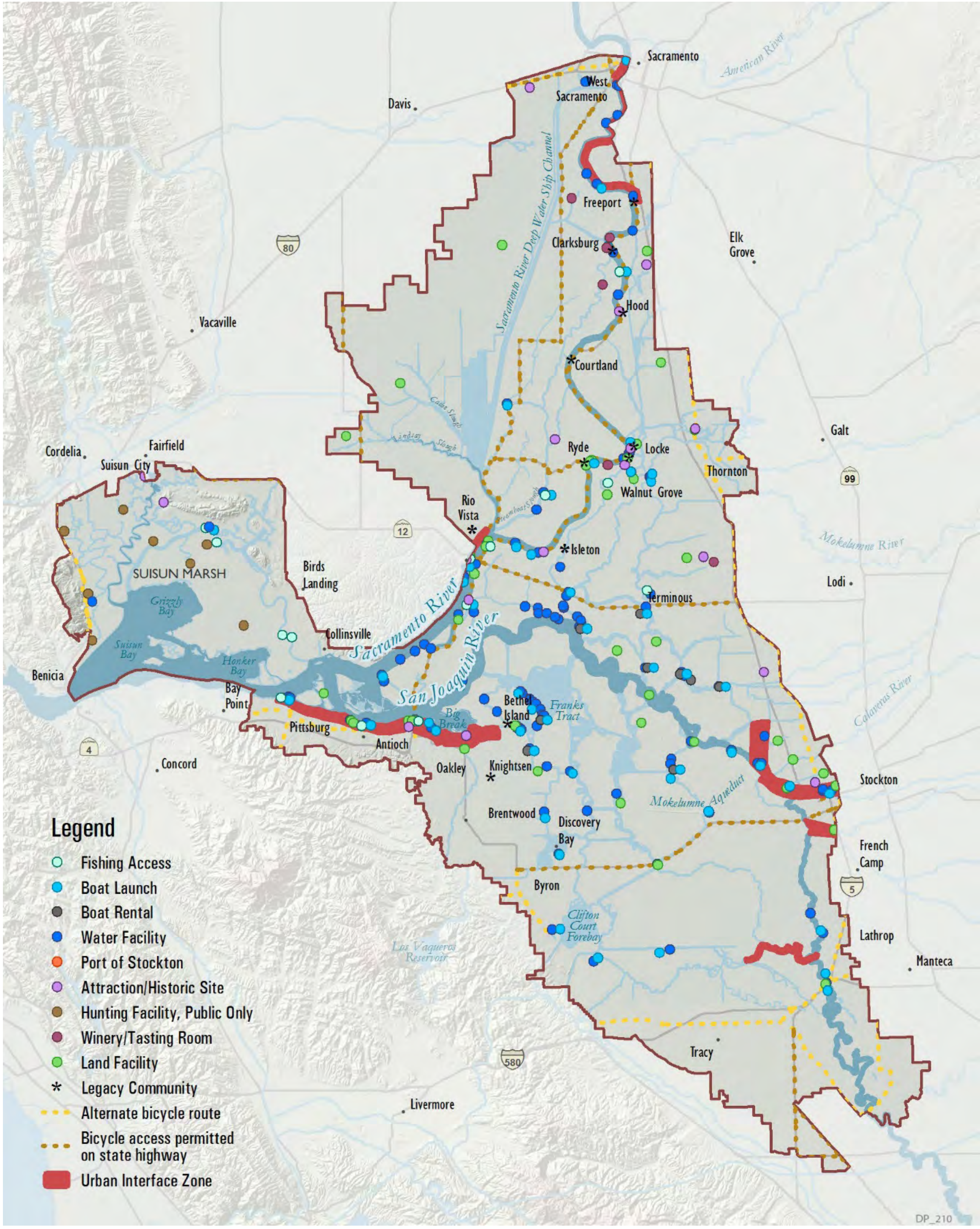


Figure 5-6

Sources: California Chambers and Visitors Bureau 2010, California Resources Agency 2007, DPC 2006, Discover the Delta Foundation 2010, California Department of Fish and Game 2009

The DPC ESP and the California State Parks Recreation Proposal both foresee opportunities to increase recreation and tourism in the Delta as the population of surrounding areas grows, especially with improved branding and marketing. Both reports emphasize improvements of "gateways" to the region on the Delta's urban edges and "base camps," focal points for visitors inside the Delta at destinations such as resorts, legacy communities, and parks. They also recommend diversifying dispersed outdoor recreation "adventures" at points of interest and activity areas for boaters, nature area visitors, and others. Ecosystem restoration, as described in Chapter 4, can enhance opportunities for nature-based recreation and boating, especially by nonmotorized boats, according to both reports.

The California State Parks Recreation Proposal recommends enhancing State parks and other State agencies' properties and programs to create a network of recreation areas in the Delta, and encourages improvement of public access along the shorelines of growing Delta communities, consistent with Water Code section 85022(d)(3). It recommends that recreation improvements be provided in new water management and habitat restoration projects unless they are inconsistent with the project purposes, in conformance with Water Code sections 11910–11915.5, or public safety. DPC's ESP also recommends that recreation facilities be included in ecosystem restoration projects when feasible. Additionally, the ESP emphasizes growing the tourism and recreation economy through private, visitor-serving businesses, and collaboration and partnerships between public- and private-sector recreation providers.

Future prospects for Delta recreation and tourism will be strongly influenced by decisions about the Delta ecosystem, water quality, levee improvements, and governance, including land use and environmental standards. The Bay Delta Conservation Plan (BDCP), Delta water quality plans, levee investments, and other decisions yet to be made can all significantly affect recreation and tourism.

Boating

Navigable waterways in the Delta and Suisun Marsh are available for public access and provide many recreational opportunities. Boating activities total more than 6.4 million visitor days annually, composed of 2.13 million annual boat trips with a projected growth to 8 million visitor days by 2020, according to the Department of Boating and Waterways. Almost 100 marinas, with more than 11,000 boat slips, and almost 60 launch ramp lanes support boating in the Delta and Suisun Marsh (DBW 2002). Popular activities include powerboating on the Sacramento and San Joaquin rivers, paddling sloughs and channels in canoes and kayaks, and sailing on the open water of Suisun and Honker bays. About 116,000 boats are registered in the five Delta counties, creating a large pool of potential recreationists (California State Parks 2011).

Public Recreation Lands

Public lands comprise about 10 percent of the Delta. State and local parks, State or national wildlife areas and refuges, ecological preserves, and other public lands provide important sites for relaxing outdoors, a family picnic, camping, and other outdoor recreation in the Delta. California State Parks owns three properties in the Delta: Brannan Island State Recreation Area and properties at Locke Boarding House-Delta Meadows and Stone Lakes. The DFW and the State Lands Commission also manage important State-owned recreation areas. The largest State ownerships are the California Department of Water Resources (DWR) lands on Sherman and Twitchell islands, which are available seasonally for hunting.

Table 5-3 summarizes the agency responsibilities, recreation-related opportunities, and examples of recreation facilities in the Delta managed by the State. City and county parks, including those of the East Bay Regional Park District, also provide important public recreation areas. These public lands are increasingly important for Delta recreation because privately owned riverbanks and levees, which comprise most of the Delta's shoreline, are increasingly posted to prevent trespass, reducing access to rivers and sloughs for bank fishing, nature observation, and outdoor relaxation.

State Agencies with Responsibility for Recreation in the Delta

TABLE 5-3

State Agency Name and Role	Recreation-related Facilities and Opportunities	Delta and Suisun Marsh Examples
California State Parks offers high-quality outdoor recreation and educational opportunities, protects natural and cultural resources, awards grants for local parks, and oversees the California Recreational Trails System.	Day-use picnic areas, campgrounds, marinas, trails, excursion railroads, interpretive services, heritage resource protection, restrooms	Brannan Island State Recreation Area, Old Sacramento State Historic Park, American Discovery Trail
California Department of Fish and Wildlife manages hunting and fishing; operates public lands for wildlife conservation, hunting, fishing, environmental education, and nature study; and encourages private conservation.	Ecological reserves, wildlife areas, boat launches, nature-based recreation and events, fish hatcheries	Woodbridge Ecological Reserve, Grizzly Island Wildlife Area, Clarksburg boat launch
California Department of Boating and Waterways provides public recreational boating facilities on public lands, marine patrol law enforcement, boating safety and clean and green education, and controls of aquatic invasive species.	Public boat launching facilities, public visitor docks, boat-in day use and overnight facilities, vessel pumpout facilities, floating restrooms, floating campsites	Antioch Marina, Brannan Island State Recreation Area, Sherman Island, Belden's Landing, Bethany Reservoir, and Rio Vista boat launch facilities
California Department of Transportation operates state highways, historic bridges, and ferries, and designates state scenic highways.	Scenic highways, ferries, historic bridges	State Highway 160, J-Mack Ferry, Steamboat Slough Bridge
California Department of Water Resources manages California's water resources, including State Water Project reservoirs, dams, land, and waterways available for recreation use.	Reservoirs, water conveyance infrastructure (canals, diversion sites, waterway flows), flood control projects, habitat management sites and facilities	Bethany Reservoir, Sacramento River flows, Fremont Weir, Suisun Marsh salinity control structure, Dutch Slough habitat restoration project
State Lands Commission has jurisdiction over hundreds of miles of waterways in the Delta and issues leases for instream recreation infrastructure.	Navigable waterways, submerged lands, dock and pier leases	Threemile Slough, Walnut Grove Public Dock

State Agencies with Responsibility for Recreation in the Delta

TABLE 5-3

State Agency Name and Role	Recreation-related Facilities and Opportunities	Delta and Suisun Marsh Examples
Sacramento-San Joaquin Delta Conservancy will implement ecosystem restoration, advance environmental protection, and support economic sustainability, including tourism and recreation.	Projects that enhance natural resources, cultural resources, or economic sustainability in a manner complementary to increased recreation, tourism, and environmental education	The Delta Plan, Bay Delta Conservation Plan, Economic Sustainability Plan, and Delta Conservancy Strategic Plan will guide projects
State Coastal Conservancy makes grants to purchase, protect, restore, and enhance coastal resources, including San Francisco Bay and Suisun Marsh, and to provide access to the shore.	Shoreline accessways, trails, habitat protection and restoration areas, farmland and open space protection	Rush Ranch protection, San Francisco Bay Area water trail, Marsh Creek stream restoration and trail
Delta Protection Commission adaptively manages the Delta's Primary Zone, including, but not limited to, agriculture, wildlife habitat, and recreation activities.	Heritage resource recognition and enhancement, agritourism program, regional trails	National Heritage Area feasibility study, Great California Delta Trail, Economic Sustainability Plan

Source: California State Parks 2011

Nature-based Recreation

Many recreation opportunities depend on the region's wildlife and fish, which support angling, nature observation, and hunting. Anglers pursue native fish, such as salmon and sturgeon, and introduced species such as striped bass, largemouth bass, and catfish. Some of the most visited public wildlife areas include the Yolo Bypass Wildlife Area, Lower Sherman Island, Calhoun and Acker Island, Stone Lakes National Wildlife Refuge, Cosumnes River Preserve, Solano County Land Trust's Jepson Prairie and Rush Ranch, and Suisun Marsh's wildlife management areas, including Grizzly Island and Joice Island. Hunting waterfowl is especially important in Suisun Marsh, most of which is managed by private duck clubs. Careful management of wildlife and fish is important to maintaining nature-based recreation, which can benefit from the restoration of fisheries and expansion of wildlife habitat.

Heritage Tourism

The Delta's legacy communities and other historic sites, from house museums to twentieth century industrial sites and weather-beaten marine facilities, attract history buffs and heritage tourists. Museums, nature centers, and interpretive programs draw visitors who want to learn about the Delta's natural and cultural resources. The region's productive farms and wineries, and its diverse ethnic heritage are attractions for food and wine tourism, and for community festivals and other special events. (Agritourism is discussed earlier in the Agriculture in the Delta section.)

Linking these areas and providing access to them are the Delta's waterways and roads. State Route 160 has a special role and provides visitors from metropolitan Sacramento and Contra Costa County with access to the Sacramento River, legacy communities, and the Delta's State parks. Its attractive rural landscape is reflected in its designation as a state scenic highway. California State Parks' Recreation Proposal recommends that the California Department of Transportation seek national scenic byway status for this route and prepare a scenic byway plan that would identify opportunities to improve signage, interpretation, and amenities for access, recreation, and nonautomobile circulation. A national scenic byway is a road recognized by the U.S. Department of Transportation for its archaeological, cultural, historic, natural, recreational, and/or scenic qualities. The program preserves and protects the nation's scenic but often less-traveled roads, and promotes tourism and economic development. Funding for byway-related projects is granted annually by the Federal Highway Administration. State Routes 4 and 12 are also important for recreational travel.

The American Discovery Trail, Mokelumne Coast-To-Crest Trail, and Great Delta Trail (Public Resources Code section 5852 et seq.) are State trails that can provide recreational access for bicyclists, hikers, and others. DPC's ESP and California State Parks' Recreation Proposal also recommend a system of water trails to guide boaters through the Delta's channels.

POLICIES AND RECOMMENDATIONS

The policies and recommendations presented in this section address the unique values that distinguish the Delta and make it a special region, and outline the Council's five core strategies for protecting and enhancing these values as follows:

- Designate the Delta as a special place worthy of national and state attention
- Plan to protect the Delta's lands and communities
- Maintain Delta agriculture as a primary land use, a food source, a key economic sector, and a way of life
- Encourage recreation and tourism that allow visitors to enjoy and appreciate the Delta and that contribute to its economy
- Sustain a vital Delta economy that includes a mix of agriculture, tourism, recreation, commercial and other industries, and vital components of state and regional infrastructure

Protecting the Delta also depends on the strategies to reduce flood and other risks, as detailed in Chapter 7.

Designate the Delta as a Special Place

Designating the Delta as a special place can build public recognition of the Delta and its unique resources. The DPC proposes to seek the Delta's designation as an NHA to recognize and promote "Delta-as-a-Place" and to cultivate appreciation and understanding of the Delta. The DPC recommends that the NHA include the legal Delta and Suisun Marsh, as well as adjoining areas in Rio Vista and the Carquinez Strait.

The proposed NHA's vision is "a regional network of partner sites, with interpretive/educational components, that will be linked where possible and serve as the primary attractions, on existing public properties or on private properties with the voluntary consent and involvement of the landowners." The NHA's goals are to "brand the Delta as a region of national significance to educate the public about 'Delta-as-a-Place,' and build more support for preserving, protecting, and enhancing the Delta." Other goals relate to economic development, public access, historic preservation, interpretation, and more.

Although State Route 160 is already recognized as a state scenic highway, national scenic byway status under the U.S. Department of Transportation and a scenic byway plan would provide opportunities to improve signage, interpretation, and amenities for access, recreation, and nonautomobile circulation. The byway program would qualify the route for special funding from the Federal Highway Administration.

Problem Statement

Because the Delta is different, it is sometimes unappreciated and misunderstood. Without a clear message about the Delta and its importance, the region and its resources can suffer from inattention or misuse. If the Delta's unique cultural, recreational, and agricultural values are not recognized, they are unlikely to be protected and enhanced.

Policies

No policies with regulatory effect are included in this section.

Recommendations

DP R1. Designate the Delta as a National Heritage Area

The Delta Protection Commission should complete its application for designation of the Delta and Suisun Marsh as a National Heritage Area, and the federal government should complete the process in a timely manner.

DP R2. Designate State Route 160 as a National Scenic Byway

The California Department of Transportation should seek designation of State Route 160 as a National Scenic Byway, and prepare and implement a scenic byway plan for it.

Plan to Protect the Delta's Lands and Communities

Protecting the Delta's lands and communities involves a multipronged policy approach. In the coming years and decades, the Delta will face increasing pressures from a growing population, changes in commodity markets, and changes in climate and sea level that will require flexibility and adaptation.

Some changes will be driven by the Delta's role in California's water systems, and they will be required to meet statewide goals of restoring the Delta's ecosystem and improving water supply reliability. These and other changes will shape how the Delta's communities and history are preserved, guide new development, affect recreation and tourism, and influence agriculture, business expansion, and economic development.

The policies and recommendations below reflect the Council's approach to fostering land uses and development that are resilient to these changes, reduce risks to people and property, adjust to changing conditions, and recover readily from distress. Protecting the Delta also depends on sustaining its economic vitality and maintaining the region as a desirable place to live, do business, and visit.

The maps that the following policies and recommendations reference are based on the best information available to the Council, but they may not precisely match either the built environment or local government land use plans. Where uncertainty exists with respect to the boundaries of areas referenced in these policies, the following rules should be considered in making determinations:

- The areas depicted should be assumed to generally follow parcel lines or other major landmarks, such as a road or highway, or river and stream.
- Local government general plans, including their land use diagrams, in effect at the time of the Delta Plan's adoption, may be consulted.

Problem Statement

Poorly sited or designed projects can detract from the values that contribute to the Delta's distinctive character, including its primarily rural, agricultural landscape; conflict with established uses, including farming and tourism; reduce opportunities for ecosystem restoration; or increase flood risks. By limiting significant new development to areas currently designated for development in cities, their SOIs, and unincorporated towns, the Council intends to foster a land use pattern that enhances the Delta's unique sense of place by protecting agriculture and the open, rural landscape while reducing risks to people and property. Outside the urban areas and towns mentioned above, in areas designated as agriculture, open space, recreation, natural preserve or marsh, or public/quasi-public, minor projects that are consistent with local land use designations, such as farmworker housing in areas designated as agriculture, are also appropriate. Similar limitations are already in place in the Primary Zone of the Delta, where the Delta Protection Act requires that new development must be consistent with the DPC's Land Use and Resource Management Plan. Additional protections for the Secondary Zone are needed. Diligent local *implementation of State law regarding flood protection in urban, urbanizing, and rural lands, and the National Flood Insurance Program will provide complementary flood protection benefits. New residential subdivisions, if any, in rural areas will also need to include adequate flood protection, as described in RR P2.*

Therefore, outside the urban areas and towns mentioned above, in areas that are designated as agriculture, open space, recreation, natural preserve or marsh, or public/quasi-public, the Council intends to enable counties to move forward with approval of minor projects that are consistent with these designations, such as farmworker housing in areas designated as agriculture. However, any proposals to site new residential development in rural areas will need to include adequate flood protection, as described in RR P2.

Careful planning for development in legacy communities is needed to protect their unique character and overcome barriers to investment. The Delta's urban areas will also continue to need sites for housing, employment, and businesses, supported by adequate roads and other infrastructure. Water management facilities, ecosystem restoration actions, and flood control projects will need to be accommodated in the Delta, too. Avoiding condemnation of property for water management, ecosystem restoration, and flood management facilities, when feasible, can promote better relations with Delta residents and local governments.

Policies

The appendices referred to in the policy language below are included in Appendix B of the Delta Plan.

DP P1. Locate New Urban Development Wisely

(a) New residential, commercial, and industrial development must be limited to the following areas, as shown in Appendix 6 and Appendix 7:

(1) Areas that city or county general plans as of May 16, 2013, designate for residential, commercial, and industrial development in cities or their spheres of influence;

(2) Areas within Contra Costa County's 2006 voter-approved urban limit line, except no new residential, commercial, and industrial development may occur on Bethel Island unless it is consistent with the Contra Costa County general plan effective as of May 16, 2013;

(3) Areas within the Mountain House General Plan Community Boundary in San Joaquin County; or

(4) The unincorporated Delta towns of Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove.

(b) Notwithstanding subsection (a), new residential, commercial, and industrial development is permitted outside the areas described in subsection (a) if it is consistent with the land uses designated in county general plans as of May 16, 2013, and is otherwise consistent with this Chapter.

(c) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions that involve new residential, commercial, and industrial development that is not located within the areas described in subsection (a). In addition, this policy covers any such action on Bethel Island that is inconsistent with the Contra Costa County general plan effective as of May 16, 2013. This policy does not cover commercial recreational visitor-serving uses or facilities for processing of local crops or that provide essential services to local farms, which are otherwise consistent with this Chapter.

(d) This policy is not intended in any way to alter the concurrent authority of the Delta Protection Commission to separately regulate development in the Delta's Primary Zone.

23 CCR Section 5010
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85022, 85300, 85302, and 85305, Water Code.

DP P2. Respect Local Land Use When Siting Water or Flood Facilities or Restoring Habitats

(a) Water management facilities, ecosystem restoration, and flood management infrastructure must be sited to avoid or reduce conflicts with existing uses or those uses described or depicted in city and county general plans for their jurisdictions or spheres of influence when feasible, considering comments from local agencies and the Delta Protection Commission. Plans for ecosystem restoration must consider sites on existing public lands, when feasible and consistent with a project's purpose, before privately owned sites are purchased. Measures to mitigate conflicts with adjacent uses may include, but are not limited to, buffers to prevent adverse effects on adjacent farmland.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions that involve the siting of water management facilities, ecosystem restoration, and flood management infrastructure.

23 CCR Section 5011
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85022, 85054, 85300, and 85305, Water Code.

Recommendations

DP R3. Plan for the Vitality and Preservation of Legacy Communities

Local governments, in cooperation with the Delta Protection Commission and Delta Conservancy, should prepare plans for each community that emphasize its distinctive character, encourage historic preservation, identify opportunities to encourage tourism, serve surrounding lands, or develop other appropriate uses, and reduce flood risks.

DP R4. Buy Rights of Way from Willing Sellers When Feasible

Agencies acquiring land for water management facilities, ecosystem restoration, and flood management infrastructure should purchase from willing sellers, when feasible, including consideration of whether lands suitable for proposed projects are available at fair prices.

DP R5. Provide Adequate Infrastructure

The California Department of Transportation, local agencies, and utilities should plan infrastructure, such as roads and highways, to meet needs of development consistent with sustainable community strategies, local plans, the Delta Protection Commission's Land Use and Resource Management Plan for the Primary Zone of the Delta, *and the Delta Plan.*

DP R6. Plan for State Highways

The Delta Stewardship Council, as part of the prioritization of State levee investments called for in Water Code section 85306, should consult with the California Department of Transportation as provided in Water Code section 85307(c) to consider the effects of flood hazards and sea level rise on State highways in the Delta.

DP R7. Subsidence Reduction and Reversal

The following actions should be considered by the appropriate State agencies to address subsidence reversal:

- *State agencies should not renew or enter into agricultural leases on Delta or Suisun Marsh islands if the actions of the lessee promote or contribute to subsidence on the leased land, unless the lessee participates in subsidence reversal or reduction programs.*
- *State agencies currently conducting subsidence reversal projects in the Delta on State-owned lands should investigate options for scaling up these projects if they have been deemed successful. The California Department of Water Resources should develop a plan, including funding needs, for increasing the extent of their subsidence reversal and carbon sequestration projects to 5,000 acres by January 1, 2017.*
- *The Delta Stewardship Council, in conjunction with the California Air Resources Board (CARB) and the Delta Conservancy, should investigate the opportunity for the development of a carbon market whereby Delta farmers could receive credit for carbon sequestration by reducing subsidence and growing native marsh and wetland plants. This investigation should include the potential for developing offset protocols applicable to these types of plants for subsequent adoption by the CARB.*

Maintain Delta Agriculture

Agriculture is the principal land use in the Delta; however, in recent decades, the total area of agricultural lands has declined, as has the overall percentage of lands in agricultural use. The continued viability of agriculture in the Delta will require the protection of sufficient farmland and fresh water to support commercially viable operations and provide ways for agriculture to coexist with habitat restoration. Policies DP P1 and DP P2 acknowledge the importance of protecting these lands. Farming in the Delta will have to respond to changing conditions and new challenges in the coming years. Among these challenges are shifting commodity markets and consumer demand, changes in climate and water supplies, and subsidence of reclaimed agricultural lands. To support both Delta agriculture and species recovery, farmers in the Delta are encouraged to implement "wildlife-friendly" management practices to maximize habitat values. Restoring wildlife and fish through wildlife-friendly agriculture can help achieve ecosystem restoration objectives while reducing the loss of farmland to habitat restoration. Agritourism is a small but fast-growing source of income for farms in the region. It is another opportunity to add further value to the Delta economy from agricultural activities.

Problem Statement

Agriculture in some parts of the Delta is threatened by urbanization, subsidence, and changing markets due to increased competition from other countries and regions, and shifting consumer preferences. The impacts from water conveyance facilities, ecosystem restoration, changing water quality, and flood management plans are yet to be determined, but rapid and significant changes could disrupt agriculture. Farmers are concerned that regulations and other barriers to conducting business and using their land also threaten the continued viability of agriculture.

Policies

No policies with regulatory effect are included in this section.

Recommendations

DP R8. Promote Value-added Crop Processing

Local governments and economic development organizations, in cooperation with the Delta Protection Commission and the Delta Conservancy, should encourage value-added processing of Delta crops in appropriate locations.

DP R9. Encourage Agritourism

Local governments and economic development organizations, in cooperation with the Delta Protection Commission and the Delta Conservancy, should support growth in agritourism, particularly in and around legacy communities. Local plans should support agritourism where appropriate.

DP R10. Encourage Wildlife-friendly Farming

The California Department of Fish and Wildlife, the Delta Conservancy, and other ecosystem restoration agencies should encourage habitat enhancement and wildlife-friendly farming systems on agricultural lands to benefit both the environment and agriculture.

Encourage Recreation and Tourism

The Delta region offers diverse recreation experiences and facilities such as fishing, boating, birdwatching, other nature activities, hunting, campgrounds, parks and picnic areas, and historic towns and buildings. DPC and California State Parks foresee opportunities to improve and increase recreation and tourism in the Delta. Both agencies recommend improvements of “gateways” to the region on the Delta’s urban edges and “base camps” inside the Delta at destinations such as resorts, legacy communities, or parks that are focal points for visitors. Building on the reports of the DPC and California State Parks, the Council recommends protecting and improving existing recreation opportunities while seeking ways of providing new, and better coordinated, opportunities. Ecosystem restoration, as described in Chapter 4, can also enhance opportunities for nature-based recreation and boating. Future prospects for recreation and tourism will be influenced by decisions about the Delta ecosystem, water quality, levee improvements, and governance, including land use and environmental standards. The BDCP, Delta water quality plans, levee investments, and other decisions yet to be made can all significantly affect recreation and tourism.

Problem Statement

Recreation opportunities abound, but many have not been fully developed due to inadequate visitor information, aging and inadequate facilities, and restricted access to public lands. Limited cooperation in marketing, planning, and public-private partnerships between public recreation providers, other government land managers, businesses, and others hinders recreation and tourism, and impedes expansion of visitor-serving businesses.

Policies

No policies with regulatory effect are included in this section.

Recommendations

DP R11. Provide New and Protect Existing Recreation Opportunities

Water management and ecosystem restoration agencies should provide recreation opportunities, including visitor-serving business opportunities, at new facilities and habitat areas whenever feasible; and existing recreation facilities should be protected, using California State Parks’ Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh *and Delta Protection Commission’s* Economic Sustainability Plan for the Sacramento-San Joaquin Delta *as guides.*

DP R12. Encourage Partnerships to Support Recreation and Tourism

The Delta Protection Commission and Delta Conservancy should encourage partnerships between other State and local agencies, and local landowners and business people to expand recreation, including boating, promote tourism, and minimize adverse impacts to nonrecreational landowners.

DP R13. Expand State Recreation Areas

California State Parks should add or improve recreation facilities in the Delta in cooperation with other agencies. As funds become available, it should fully reopen Brannan Island State Recreation Area, complete the park at Delta Meadows-Locke Boarding House, and consider adding new State parks at Barker Slough, Elkhorn Basin, the Wright-Elmwood Tract, and south Delta.

DP R14. Enhance Nature-based Recreation

The California Department of Fish and Wildlife, in cooperation with other public agencies, should collaborate with nonprofits, private landowners, and business partners to expand wildlife viewing, angling, and hunting opportunities.

DP R15. Promote Boating Safety

The California Department of Boating and Waterways should coordinate with the U.S. Coast Guard and State and local agencies on an updated marine patrol strategy for the region.

DP R16. Encourage Recreation on Public Lands

Public agencies owning land should increase opportunities, where feasible, for bank fishing, hunting, levee-top trails, and environmental education.

DP R17. Enhance Opportunities for Visitor-serving Businesses

Cities, counties, and other local and State agencies should work together to protect and enhance visitor-serving businesses by planning for recreation uses and facilities in the Delta, providing infrastructure to support recreation and tourism, and identifying settings for private visitor-serving development and services.

Sustain a Vital Delta Economy

Many of the policies and recommendations in this chapter deal with aspects of the Delta's economy such as maintaining agriculture and encouraging recreation and tourism. The Delta's economy also benefits from the surface transportation, utilities, and other infrastructure that crisscross the Delta to serve local needs and link the Delta to regional, national, and global markets. Facilities such as natural gas wells, wind turbines, other renewable power sources, electric transmission lines, and fuel pipelines need to be planned carefully to avoid conflicts with water supply, ecosystem restoration, or flood management facilities and existing and planned land uses. The ports at Stockton and West Sacramento are valuable assets to Delta communities and the state. Areas for water-dependent industries are located in Collinsville, Rio Vista, Pittsburg, and Antioch.

Problem Statement

Other economic opportunities in the Delta, including port and energy uses, could suffer if unplanned development, flooding, or other land uses interfere with them.

Policies

No policies with regulatory effect are included in this section.

Recommendations

DP R18. Support the Ports of Stockton and West Sacramento

The ports of Stockton and West Sacramento should encourage maintenance and carefully designed and sited development of port facilities.

DP R19. Plan for Delta Energy Facilities

The California Energy Commission and California Public Utilities Commission should cooperate with the Delta Stewardship Council as described in Water Code section 85307(d) to identify actions that should be incorporated in the Delta Plan by 2017 to address the needs of Delta energy development, storage, and distribution.

Timeline for Implementing Policies and Recommendations

Figure 5-7 lays out a timeline for implementing the policies and recommendations described in the previous sections. The timeline emphasizes near-term and intermediate-term actions.

Timeline for Implementing Policies and Recommendations

TIMELINE

CHAPTER 5: Delta as an Evolving Place

	ACTION (REFERENCE #)	LEAD AGENCY(IES)	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025
POLICIES	Locate new urban development wisely (DP P1)	Local governments	●	●
	Respect local land use when siting water or flood facilities or restoring habitats (DP P2)	Local governments and State agencies	●	●
RECOMMENDATIONS	Designate the Delta as a National Heritage Area (DP R1)	DPC	●	
	Designate State Route 160 as a National Scenic Byway (DP R2)	Caltrans	●	
	Plan for the vitality and preservation of legacy communities (DP R3)	Local governments, DPC, Delta Conservancy	●	
	Buy rights of way from willing sellers when feasible (DP R4)	Local, State, and federal agencies	●	●
	Provide adequate infrastructure (DP R5)	Caltrans, local agencies, and utility providers	●	●
	Plan for State highways (DP R6)	Council, Caltrans	●	
	Subsidence reduction and reversal (DP R7)	State agencies	●	
	Promote value-added crop processing (DP R8)	Local governments and economic development organizations	●	●
	Encourage agritourism (DP R9)	Local governments and economic development organizations	●	●
	Encourage wildlife-friendly farming (DP R10)	DFW, Delta Conservancy	●	●
	Provide new and protect existing recreation opportunities (DP R11)	Water management and ecosystem restoration agencies	●	●
	Encourage partnerships to support recreation and tourism (DP R12)	DPC, Delta Conservancy	●	●
	Expand State Recreation Areas (DP R13)	Parks	●	●
	Enhance nature-based recreation (DP R14)	DFW	●	●
	Promote boating safety (DP R15)	Boating and Waterways	●	
	Encourage recreation on public lands (DP R16)	DWR, DFW, Delta Conservancy, Parks	●	
	Enhance opportunities for visitor-serving businesses (DP R17)	Local governments and State agencies	●	●
	Support the Ports of Stockton and West Sacramento (DP R18)	Ports of Stockton and West Sacramento	●	●
	Plan for Delta energy facilities (DP R19)	California Energy Commission and PUC	●	

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Agency Key:

Boating and Waterways: California Department of Boating and Waterways
Delta Conservancy: Sacramento-San Joaquin Delta Conservancy
Caltrans: California Department of Transportation
Council: Delta Stewardship Council
DFW: California Department of Fish and Wildlife
DPC: Delta Protection Commission
DWR: California Department of Water Resources
Parks: California State Parks
PUC: California Public Utilities Commission

Figure 5-7

Science and Information Needs

Better information about recreation and tourism in the Delta and additional research into best practices for managing farmlands in the Delta can contribute to efforts to protect the Delta's unique values. These needs include the following:

- Surveys of Delta recreation at regular intervals, such as every 5 years, to inform marketing and planning for recreation and tourism
- Assessments of opportunities to control or reverse subsidence of farmland
- Analysis of land and water use by agriculture, including land ownership (resident vs. absentee; age of owner; size of holding, etc.), cropping patterns, soil types, and other factors to identify the Delta's agricultural regions, their competitive advantages, threats and opportunities
- Analysis of farm labor housing needs.

Issues for Future Evaluation and Coordination

Many Delta agencies and residents are concerned that the region's economy may suffer if agriculture or other uses decline significantly due to habitat restoration or water conveyance projects, especially the BDCP described in Chapter 3, or changes in State priorities for levee investment resulting from the studies recommended in Chapter 7. DPC's ESP forecasts adverse economic impacts from farmland loss based on a scenario of how these decisions may affect the region. Its Proposal to Protect the Delta as a Place recommends that the Delta Investment Fund support protection of the Delta economy, and be administered by the DPC and guided by an investment committee appointed by the DPC's commissioners (DPC 2012a). The Delta Conservancy will also play a role in some economic development efforts, as provided in Public Resources Code section 32322(b).

Because BDCP and new levee investment priorities are not yet complete, the magnitude of any impacts to farmland, other uses, or the Delta's economy cannot reasonably be forecast. If significant adverse impacts to the Delta economy do result from farmland losses or other impacts due to habitat restoration, water conveyance, or revised levee investment priorities, then measures to compensate for these losses may warrant consideration. This consideration should include creation of a regional agency to implement and facilitate economic development efforts, guided by the DPC's ESP. The agency's responsibilities could include the following:

- Branding and marketing the Delta
- Coordinating with counties and cities to encourage planning and infrastructure development that is aligned with economic sustainability strategies
- Providing regulatory assistance to reduce impediments to priority activities, including visitor-serving developments, dredging, levee construction, and ecosystem restoration, to reduce impediments and lower costs of these activities
- Encouraging value-added processing of Delta crops, agritourism, visitor-serving commercial businesses, and preservation of the historic buildings in legacy communities
- Recommending and overseeing expenditures from the Delta Investment Fund

Performance Measures

Development of informative and meaningful performance measures is a challenging task that will continue after the adoption of the Delta Plan. Performance measures need to be designed to capture important trends and to address whether specific actions are producing expected results. Efforts to develop and track performance measures in complex and large-scale systems like the Delta are commonly multiyear endeavors. The recommended output and outcome performance measures listed below are provided as examples and subject to refinement as time and resources allow. Final administrative performance measures are listed in Appendix E and will be tracked as soon as the Delta Plan is completed.

Recommended performance measures for protection and enhancement of the unique cultural, recreational, natural resources, and agricultural values of the Delta as an evolving place are described below.

Output Performance Measures

- Congress designates the Delta and Suisun Marsh as an NHA by January 1, 2014. (DP R1)
- Water management, ecosystem restoration, and flood management projects minimize conflicts with adjoining uses by including adequate mitigation measures to avoid adverse effects. (DP P2)
- Recreation facilities are included in new ecosystem restoration projects. (DP R9)
- The DWR and others increase the extent of their subsidence reversal and carbon sequestration projects to 5,000 acres by January 1, 2017. (DP R7)

Outcome Performance Measures

- No further rural farmland in the Delta is lost to urban development. (DP P1)
- Progress toward protecting the Delta legacy communities, as indicated by renovation of historic structures, floodproofing, and other reductions in flood hazards, and maintenance or growth of small businesses and population. (DP R3)
- Increasing tonnage of cargo and the number of jobs at the ports of Stockton and West Sacramento. (DP R18)

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CHAPTER 6

Improve Water Quality to Protect Human Health and the Environment

ABOUT THIS CHAPTER

This chapter discusses the trade-offs and conflicts inherent in managing water quality for multiple objectives. It recommends strategies to make balanced improvements primarily through the prioritization of projects and programs. It also provides support to related information in Chapters 3, 4, and 5.

Other State of California (State) agencies have broad authority to protect and regulate water quality. This chapter sets forth priority Sacramento-San Joaquin Delta (Delta)-specific recommendations for those agencies and focuses on four core strategies where best available science shows the need for improved water quality to achieve the coequal goals:

- Require Delta-specific water quality protection
- Protect beneficial uses by managing salinity
- Improve drinking water quality
- Improve environmental water quality

These core strategies form the basis of the 12 recommendations found at the end of this chapter. These major aspects are critical to protecting human health and improving the environment. Salinity is discussed in a separate section because of its importance as a defining characteristic of the estuary and its implications to ecosystem health, its linkage to water project operations, and its historical importance in the Delta.

RELEVANT LEGISLATION

The protection and improvement of water quality is inherent to meeting the coequal goals of the State. Water quality plays a critical role in the achievement of a more reliable water supply and protection, restoration, and enhancement of the Delta ecosystem. Water quality also contributes to the values of the Delta as an evolving place. The Sacramento-San Joaquin Delta Reform Act of 2009 calls for improving water quality as follows:

> *85020 The policy of the State of California is to achieve the following objectives that the Legislature declares are inherent in the coequal goals for management of the Delta:...(e) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.*

85022(d) The fundamental goals for managing land use in the Delta are to do all of the following: ... (6) Improve water quality to protect human health and the environment consistent with achieving water quality objectives in the Delta.

85302(d) The Delta Plan shall include measures to promote a more reliable water supply that address all of the following: ... (3) Improving water quality to protect human health and the environment.

85302(e) The following subgoals and strategies for restoring a healthy ecosystem shall be included in the Delta Plan... (5) Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals.

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CHAPTER 6

Improve Water Quality to Protect Human Health and the Environment

The Delta Reform Act acknowledges water quality as an important element of a reliable water supply and directs the Delta Stewardship Council (Council) to improve water quality to protect human health and the environment. In general, water quality is an abstract concept unless it is discussed relative to protection of the beneficial uses of that water. The Delta Reform Act highlights drinking water, agriculture, and ecosystem goals as important beneficial uses for the purpose of the Delta Plan. The Council's role with respect to water quality is to ensure that the policies and recommendations in the Delta Plan balance the protection of myriad—and sometimes competing—beneficial uses of water.

In California, the entities primarily responsible for managing water quality in the state are the nine regional water quality control boards (RWQCBs) and the State Water Resources Control Board (SWRCB). The RWQCBs are responsible for water quality planning, permitting and enforcement, and financial assistance, when funds are available. The SWRCB is responsible for statewide plans, permits, and policies, and serves as a review body for RWQCB decisions. The SWRCB also has the important and challenging task of administering the State's complex water rights system of permits and licenses. As part of these duties, the SWRCB sets water quality objectives for major waterways, including the tributaries of the Delta, as described in Chapter 4. The Central Valley RWQCB is the regional board with primary jurisdiction in the Delta and Delta watershed.

Water quality in the Delta is influenced by many factors. Seasonal rainfall, snow runoff, and reservoir releases flow in from several rivers and streams, primarily the Sacramento and the San Joaquin rivers. During very high flows, some of this water flows across floodplains before it enters the Delta. Tides can bring saline waters into the Delta from the San Francisco Bay. There are also discharges from cities, industries, and agricultural lands. As all of these flows enter the Delta, they bring with them a variety of contaminants. Additionally, water is diverted from the Delta, either for use within the Delta or for use in Central and Southern California and other service areas. The timing and physical qualities of these flows into and out of the Delta affect the water quality needed to support the beneficial uses of Delta waters.

In achieving the coequal goals, the Council envisions a Delta where improved water quality supports a healthy ecosystem and the multiple beneficial uses of water, including municipal supply and recreational uses such as fishing and swimming. To support a more resilient and healthy Delta ecosystem, salinity patterns should be consistent with more natural flow patterns with inflows of high-quality water. Nutrient concentrations should support diverse and productive aquatic food webs, and should not cause excessive growth of nuisance aquatic plants or blooms of harmful algae. Physical attributes of the aquatic environment, such as dissolved oxygen (DO) concentrations, temperature ranges, and turbidity levels, should support the needs of native species. At all times, the Delta should be free of harmful concentrations of toxic substances. Discharges of treated wastewater, urban runoff, or agricultural return flows should be regulated so that they do not have a negative effect on the Delta. High water quality is imperative to the coequal goals and crucial for protecting the beneficial uses of Delta water, successful restoration of aquatic habitats, and sustenance of native plants and animals.

Beneficial uses of Delta waters involve trade-offs that are important to recognize and address when establishing water quality goals. These trade-offs emerge in cases where acceptable or even ideal water quality for one use may have unintended or adverse effects on another use. For example, variable salinity levels are beneficial for many native species in the Delta, but can be problematic for agricultural or municipal uses. Bromide salts, one component of salinity, can result in cancer-causing disinfection byproducts with some water treatment methodologies. Similarly, organic carbon in drinking water sources can contribute to harmful disinfection byproduct formation (Leenheer and Croue 2003). However, for ecosystem purposes, organic carbon is beneficial and is increased by wetland creation. Also, wetland creation can result in increased methylation of mercury, resulting in bioaccumulation of mercury in fish species, a threat to human health when these fish are consumed. Water quality is strongly connected to water supply, as reservoir releases to control salinity can reduce the availability of fresh water at times of the year when it is needed most. These and other issues affecting water quality policy are discussed in this chapter.

Beneficial Uses of Water in and from the Delta

A goal of the Delta Plan is to maintain water quality at a level that supports and enhances designated beneficial uses. Table 6-1 lists the beneficial uses for water in the Delta as specified in the SWRCB's 2006 *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary* (Bay-Delta Plan).

The most important part of any water quality discussion is identifying the existing and potential uses of the water in question. These uses drive the level of water quality that must be attained, and what requirements and limitations must be placed on dischargers and diverters of that water to protect those uses. Specific discharge limitations are based on adopted science-based objectives necessary to protect associated beneficial uses. These limitations are then included in discharge permits.

Factors Influencing Water Quality in the Delta

This section provides an overview of factors that influence water quality in the Delta and existing water quality regulations. Water quality in the Delta is influenced by factors such as:

- Freshwater inflows and outflows
- In-Delta land use
- Dredging
- The Delta levee system
- Tides
- Point source inputs of pollutants
- Nonpoint source inputs of pollutants
- In-Delta water use
- Export diversions and operations

Delta Water Beneficial Uses

TABLE 6-1

Beneficial Use	Description
Municipal and Domestic Supply	Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.
Industrial Service Supply	Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.
Industrial Process Supply	Uses of water for industrial activities that depend primarily on water quality.
Agricultural Supply	Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.
Groundwater Recharge	Uses of water for natural or artificial recharge of groundwater for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.
Navigation	Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.
Water Contact Recreation	Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These include, but are not limited to, swimming, wading, water skiing, skin and scuba diving, surfing, white-water activities, fishing, or use of natural hot springs.
Non-contact Water Recreation	Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion is reasonably possible. These include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.
Shellfish Harvesting	Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial, or sports purposes.
Commercial and Sport Fishing	Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.
Warm Freshwater Habitat	Uses of water that support warmwater ecosystems including, but not limited to, preservation of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Cold Freshwater Habitat	Uses of water that support coldwater ecosystems including, but not limited to, preservation or enhancements of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.
Migration of Aquatic Organisms	Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.
Spawning, Reproduction, and/or Early Development	Uses of water that support high-quality aquatic habitats suitable for reproduction and early development of fish.
Estuarine Habitat	Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).
Wildlife Habitat	Uses of water that support estuarine ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.
Rare, Threatened, or Endangered Species	Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under State or federal law as being rare, threatened, or endangered.

Source: SWRCB 2006

Generally, water quality is better in the northern Delta than in the central and southern Delta because higher-quality Sacramento River inflows are greater than inflows from the San Joaquin River, and the proportion of agricultural water use and drainage in the San Joaquin Valley is greater than in the Sacramento Valley. The SWRCB has listed Delta waterways (various streams, rivers, and sloughs in the Delta), the Carquinez Strait, and San Francisco Bay as having impaired water quality pursuant to the federal Clean Water Act (CWA) section 303(d) list[1] (SWRCB 2010). Pollutants of concern include insecticides, herbicides, mercury, selenium, nutrients, and legacy organic pollutants such as dichlorodiphenyltrichloroethane (DDT) and polychlorinated biphenyls (PCBs). Additional water quality issues in the Delta include temperature, salinity, turbidity, low DO, bromide, dissolved organic carbon, pathogens, and harmful algal blooms (HABs). Amounts of these constituents that are too high (or in some cases too low) can impair the ability of these waters to support beneficial uses, such as municipal water supply, recreational use, agricultural water supply, and habitat that supports healthy fish and wildlife populations. See Chapter 4 for additional discussion on how these water quality stressors can affect the Delta and its ecosystem.

Protecting Water Quality Is a Balancing Act

Water quality is central to the State's goals for the Delta – restoring the Delta ecosystem and providing for a more reliable water supply, while protecting and enhancing the Delta as a unique and evolving place. Conditions that affect water quality must be managed and balanced in a way that allows these goals to be met simultaneously. When one use is protected, steps must be taken to minimize impacts on other uses. The following examples of this interconnectedness illustrate the difficulty of the challenge at hand.

Water supply for agricultural, municipal, and industrial use requires control of chemical constituents such as salinity, and certain pollutants that could pose a threat to human health. Efforts to protect, enhance, and restore the Delta ecosystem, however, require the management of volume and timing of flows to provide beneficially variable salinity for certain species and sufficient fresh water for others. This management regime must also consider management of nutrients and suspended solids to ensure a viable food chain within the Delta.

Protecting the communities within the Delta and their water use involves many of these same salinity and pollutant controls that are important for any water supply, but water quality in the Delta must also support recreational uses such as swimming, fishing, and boating. Cumulative discharges of pollutants from Delta communities and from recreational craft can affect in-Delta uses. Sea level rise caused by climate change will affect in-Delta water use and the manner in which flows are managed to meet water quality demands. Levee construction and placement is important to guard against flooding that could threaten in-Delta and exported water supplies. In addition, levee construction can either disrupt ecosystem processes or help provide important habitat benefits, depending on the project's location and individual attributes.

Climate Change

Impacts on water quality from climate change are difficult to predict. However, a recent analysis by the U.S. Geological Survey (USGS) suggests that climate change poses a significant threat to water quality (Cloern et al. 2011). Increases in sea level would increase salinity intrusion into the Delta, threatening water quality for agricultural and municipal uses. Increased air and water temperatures would result in increased runoff amounts in winter, with less in spring and summer. Warmer water can directly affect the life cycle of many fish species and stimulate growth of nuisance aquatic plants or blooms of harmful algae, which can lead to

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[1] The "303(d) list" is the list of impaired and threatened waters (stream/river segments, lakes) that states have identified as not meeting water quality standards and other requirements. Under section 303(d), the law requires that states establish priority rankings for waters on the list and develop total maximum daily loads (TMDLs) for these waters.

decreases in DO and increases in organic carbon. Increased runoff in the winter could result in more erosion and greater pulses of pollutants.

Existing Water Quality Regulations

Many different agencies have a role in the regulation of water quality in the Delta. The SWRCB and the RWQCBs have primary responsibility over discharges affecting beneficial uses of water in California with the oversight of the U.S. Environmental Protection Agency (USEPA). Drinking water supply is regulated by the California Department of Public Health, also with oversight by USEPA. Additionally, the California Department of Pesticide Regulation regulates the sale and use of pesticides, which affect water quality. (See sidebar, A Water Quality Success Story.)

A WATER QUALITY SUCCESS STORY

Widespread use of the organophosphorus pesticide diazinon in the Central Valley and episodes of aquatic toxicity caused the Central Valley RWQCB to add the Sacramento and Feather rivers to its list of impaired water bodies in 1994. A total maximum daily load for diazinon was adopted in 2003. Stakeholders also took action to implement a diazinon control strategy, and the USEPA and California Department of Pesticide Regulation took steps to restrict approved uses of diazinon. Grants from the USEPA, the former CALFED Bay-Delta Program, and other agencies provided funding support for control program implementation and research throughout the Central Valley region, including the San Joaquin River.

These water quality control efforts have helped to reduce levels of diazinon to the point that violations of water quality standards in the Sacramento and San Joaquin rivers are rare. Although pesticide pollution is still a problem in parts of some Central Valley streams and rivers, the experience with diazinon shows that programs to address these and other water quality problems can be effective (USEPA 2010).

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The RWQCBs develop water quality control plans (known as Basin Plans) that establish water quality standards and implementation plans for achieving standards for all surface water and groundwater in their respective regions. Water quality standards include identification of beneficial uses, numeric and narrative water quality objectives to protect those uses, and water quality control policies. The RWQCBs issue discharge permits and requirements that specify the amounts of pollutants that may be discharged based on these objectives. Although these permits are intended to ensure protection of these beneficial uses, some water bodies continue to exceed standards, and beneficial uses are not being protected. These impaired water bodies are identified and listed pursuant to federal CWA section 303(d).

Placement of a water body on the CWA 303(d) list initiates a process to develop a pollution limit, or total maximum daily load (TMDL), to address each pollutant causing the impairment. A TMDL defines how much of a pollutant a water body can tolerate and still meet water quality standards. The TMDL must account for all sources of a pollutant, including point sources and nonpoint sources (discharges from wastewater treatment facilities; runoff from urban areas, agricultural inputs, and streets or highways; “toxic hot spots”; and aerial deposition). In addition to accounting for past and current activities, TMDLs may also consider projected future population growth that could increase pollutant levels. The TMDL identifies allocations for point sources and for nonpoint sources, and includes a margin of safety to account for uncertainty. An implementation plan is developed that specifies a set of actions that must be carried out to ensure that the TMDL results in achievement of water quality standards. TMDLs are usually implemented through amendments to the appropriate Basin Plan, which, in turn, will result in changes to discharge permits as they are reissued. Once a TMDL is approved, it may be some time before the necessary studies are completed to set and apportion specific discharge limitations among all dischargers and potential dischargers.

The 2008-2010 Integrated Report (SWRCB 2010), which includes the 303(d) list, prioritizes TMDLs to be developed for each water body-pollutant combination on the CWA section 303(d) list, and establishes schedules for completion of the TMDLs. Approved TMDLs and TMDLs under development are listed in Table 6-2.

On February 10, 2011, the USEPA issued an Advanced Notice of Proposed Rulemaking (USEPA 2011) as part of an effort to assess the effectiveness of current water quality programs designed to protect aquatic species in the San Francisco Bay and the Delta (referred to here as the Bay-Delta). The document identified key water quality issues affecting Bay-Delta aquatic resources and summarized current research for each of these issues, including total ammonia, selenium, pesticides, emerging contaminants, and other parameters affecting estuarine habitat and the migratory corridors of anadromous fish. The notice was intended to solicit public comment on possible USEPA actions to address water quality conditions affecting the Bay-Delta. USEPA may make changes to programs in the Bay-Delta through a formal rulemaking process as a result of further evaluation and consideration of public comment. These changes could affect federal water quality programs administered by the State.

Water quality in the Delta is also regulated by the San Francisco Bay Conservation and Development Commission (BCDC), which has jurisdiction on all tidal areas of the Bay, including Suisun Bay and Suisun Marsh. BCDC policies regarding water quality are intended to prevent the release of pollution into Bay waters to the greatest extent feasible. The BCDC makes decisions regarding water quality impacts based on evaluation by and the advice of the San Francisco Bay RWQCB. The BCDC reviews State and federal actions, permits, projects, licenses, and grants affecting the Bay, including Suisun Marsh, pursuant to the federal Coastal Zone Management Act.

In the Delta and the Suisun Marsh, the Bay-Delta Plan establishes water quality objectives for which implementation is achieved through assigning responsibilities to water right holders and water users (SWRCB 2006). (See sidebar, Water Board Regulation and the Bay-Delta Plan.) This is because the parameters to be controlled are significantly affected by flows and diversions; these responsibilities were established in Water Rights Decision 1641 in 1999. The Bay-Delta Plan also provides protection for beneficial uses that require control of salinity and operations of the various water projects in the Delta, including the State Water Project (SWP) and Central Valley Project (CVP) (SWRCB 2006).

TMDLs Approved and under Development in the Central Valley, Delta, and Suisun Bay

TABLE 6-2

Water Bodies	Pollutants	Status
American River	Mercury	Under Development
Cache Creek, Bear Creek, Harley Gulch	Mercury	Approved
Central Valley	Organochlorine Pesticides	Under Development
Central Valley	Pesticides	Under Development
Clear Lake	Mercury	Approved
Clear Lake	Nutrients	Approved
Grasslands	Selenium	Approved
North San Francisco Bay (includes Suisun Bay)	Selenium	Under Development
Sacramento and Feather Rivers	Diazinon	Approved
Sacramento County Urban Creeks	Diazinon and Chlorpyrifos	Approved
Sacramento-San Joaquin River Delta	Diazinon and Chlorpyrifos	Approved
Sacramento-San Joaquin River Delta	Mercury	Approved
Salt Slough	Selenium	Approved
San Francisco Bay (includes Suisun Bay)	Mercury	Approved
San Francisco Bay (includes Suisun Bay)	PCBs	Approved
San Francisco Bay Area Urban Creeks	Diazinon/Pesticide Toxicity	Approved
San Joaquin River	Salt and Boron	Approved
San Joaquin River	Diazinon and Chlorpyrifos	Approved
San Joaquin River	Selenium	Approved
Stockton Deep Water Ship Channel (Phase 1)	Dissolved Oxygen	Approved
Stockton Deep Water Ship Channel (Phase 2)	Dissolved Oxygen	Under Development
Stockton Urban Sloughs	Dissolved Oxygen	Under Development
Stockton Urban Water Bodies	Pathogens	Approved
Suisun Marsh	Dissolved Oxygen	Under Development
Suisun Marsh	Mercury	Under Development
Upper Sacramento River	Cadmium, Copper, and Zinc	Approved

Sources: Central Valley RWQCB 2011; San Francisco Bay RWQCB 2011a

The SWRCB and RWQCBs are the regulatory agencies with statutory authority to adopt water quality control plans, including regulating waters for which water quality standards are required by the federal CWA (Water Code sections 13170 and 13240). The Council recognizes the SWRCB's role and authority in regulating water quality, and supports and encourages the timely development and enforcement of programs (for example, water quality objectives and waste discharge requirements (WDRs), TMDLs, and National Pollutant Discharge Elimination System [NPDES] permits) to reduce pollutant loads that are causing water quality impairments in the Delta. The Council also supports and encourages the completion of the elements of the SWRCB's 2010 *Update to Strategic Plan 2008-2012* (June 2010) and the *Strategic Workplan for Activities in the San Francisco Bay/Sacramento–San Joaquin River Delta Estuary* (July 2008) prepared by the SWRCB, Central Valley RWQCB, and San Francisco Bay RWQCB.

WATER BOARD REGULATION AND THE BAY-DELTA PLAN

Water Quality Criteria, Objectives, and Standards. The SWRCB and RWQCBs have primary responsibility for the regulation of discharges and control of pollutants that affect California's surface and groundwater resources.

The water boards do this by using scientific studies and information to first determine the water quality *criteria* that are needed for specific beneficial uses of that water. Examples of beneficial uses include drinking water use, agricultural use, recreation, and others listed in the Bay-Delta Plan. The water quality criteria are then used to develop water quality objectives.

Water quality *objectives* account for additional information such as economic impacts, effects on other uses, available technology, and similar factors. Water quality objectives are considered equivalent to water quality *standards* required by the USEPA. The RWQCBs adopt water quality control plans that contain these objectives; they identify specific beneficial uses of each water body covered by that plan and specific water quality objectives to protect those uses. These plans are then used to issue general or site-specific discharge permits with specific pollutant discharge limitations.

Section 303(d) of the federal CWA requires that California create a listing of impaired water bodies that are not meeting water quality standards. Water bodies on this 303(d) list require development of a TMDL, which establishes a limitation on the amount of pollution that water body can be exposed to without adversely affecting its beneficial uses. This TMDL allocates proportions of the total limitation among dischargers to the impaired surface water. TMDLs typically result in changes to water quality control plans, so that existing and future permits contain pollutant limits or other provisions necessary to ensure that the water quality standards are met.

Flow Objectives. The SWRCB is responsible for administering and overseeing the right to take and use water in California. Where storage, transport, diversion, and use of water threaten to adversely affect water quality and beneficial uses, the SWRCB may adopt plans that set objectives for water quality and flow where necessary to protect beneficial uses. As a special kind of water quality objective, *flow objectives* are developed on the basis of scientifically developed information and account for other factors, such as economic impacts, physical constraints, and effects on other uses such as water supply and agricultural use.

The Bay-Delta Plan. In the case of the Delta, the SWRCB has adopted the Bay-Delta Plan. This plan contains water quality objectives, including flow objectives. The Delta Reform Act required that certain flow criteria be developed, which the SWRCB completed in 2010.

In early 2012, the SWRCB officially launched the comprehensive review of the Bay-Delta Plan. The water quality control planning phase of this review will include review of potential modifications to current objectives included in the Bay-Delta Plan, the potential establishment of new objectives, and modifications to the program of implementation for those objectives. It will also include potential changes to the monitoring and special studies program included in the Bay-Delta Plan. The water quality control planning process will not include amendments to water rights and other measures to implement a revised Bay-Delta Plan. A separate environmental impact report will be prepared for these actions. In addition, a separate substitute environmental document is being prepared to address updates to the water quality objectives for the protection of southern Delta agricultural beneficial uses, San Joaquin River flow objectives for the protection of fish and wildlife beneficial uses, and the program of implementation for those objectives.

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Salinity in the Delta

The Delta is an estuary, and like any estuary, fresh water from rivers and tributaries flows downstream where it mixes with salt water. The location, extent, and dynamics of the freshwater-saltwater interface are important drivers of many estuarine (ecological) processes and important considerations in water management for human uses. The geographic extent of water of the correct salinity is important to many estuarine species as it is an important characteristic of their habitat. Crops vary in their tolerance of salt content in water used for irrigation, and salinity can reduce yields of sensitive crops at relatively low levels. Salt in municipal water supplies increases corrosion of pipes and appliances, can affect taste, and can contribute to the formation of disinfection byproducts that are harmful to human health. The management-intensive regulation of salinity in the Delta for multiple benefits is another example of the highly altered system the Delta has become. This section provides a summary of the history of Delta salinity problems and the effects of salinity on agricultural, municipal, and industrial water use.

History and Causes of Delta Salinity Problems

The location of the freshwater-saltwater interface in the estuary shifts with the seasons and the tides and from year to year depending on the amount of precipitation, water diversions, and Delta outflow (Kimmerer 2004; Malamud-Roam et al. 2007; Stahle et al. 2011). The location, extent, and dynamics of this freshwater-saltwater gradient have changed over the past 150 years because of landscape modification, water management and flood management infrastructure such as dams and conveyance facilities, channel dredging, and climate change.

Figure 6-1 is a representation of salinity over a range of concentrations relevant to suitability for water supply. It shows the salinity gradient in the western Delta under high and low outflow conditions. Changes in seasonal inflow to the Delta caused by upstream diversions, storage of water behind the State and federal water project dams, and operation of the State and federal Delta pumps have generally shifted the salinity gradient upstream and have changed seasonal and interannual salinity patterns. Even with these measurable shifts in salinity caused by diversion, storage, and conveyance of water, a primary driver of seasonal and annual salinity variability in the western Delta and Suisun Marsh continues to be the amount of precipitation in the watershed (Enright and Culberson 2010).

The examination of tree rings throughout the mountains of California provides a good indicator of precipitation over the last 650 years, but tree rings alone cannot accurately reproduce the details of Delta salinity over this period (Stahle et al. 2011). However, strong evidence indicates that the western Delta was a freshwater ecosystem for 2,500 years before human modification in the nineteenth and twentieth centuries (Malamud-Roam and Ingram 2004). Channel dredging, significant reductions in tidal marsh area, and levee construction have changed Delta salinity by increasing the strength of tides in the Delta, increasing connections between channels, and reducing the moderating effects of wetlands and floodplains on outflow. Consequently, simply allowing more variability in Delta outflow will not produce the same salinity patterns that existed before development.

Although sea water is the primary source of salinity in the western Delta and Suisun Marsh, it is not the only source. Agricultural drainage is another significant source of salinity, particularly in the San Joaquin Valley. Municipal and industrial discharges also can locally increase salinity, although such salinity increases are generally small compared to increases from brackish water inputs. All surface waters and groundwaters contain some amount of salt, and this salt is concentrated with use through evaporation and transpiration of water by plants (Central Valley Drinking Water Policy Workgroup 2007). The remaining water in drainage, agricultural return flows, or percolated groundwater has a higher salt concentration than the supply water. This normal increase in salinity with water use is exacerbated in some parts

Salinity in the Delta Varies by Inflow Volumes

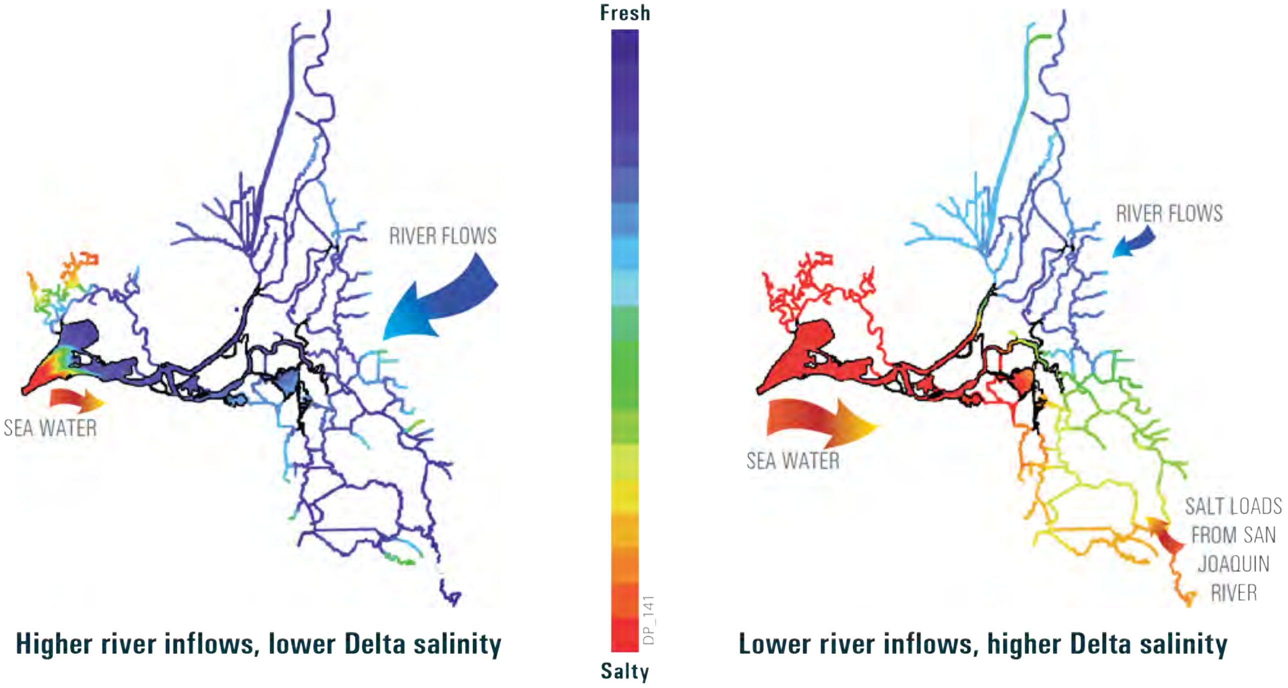

Figure 6-1

Delta salinity varies with inflow and outflow. Very high flows (left) push fresh water well into Suisun Bay and produce low-salinity conditions throughout the Delta. During very low flow periods (right), sea water can be seen pushing into the interior Delta from Suisun Bay with high salinity also entering from the San Joaquin River in the southeastern Delta.

Source: Central Valley Drinking Water Policy Workgroup 2007; images created by Resource Management Associates

of the San Joaquin Valley by naturally occurring salts in soils and a Delta water supply that already includes salt. Some of the salt load in the San Joaquin Valley accumulates in groundwater, affecting a variety of uses. Another manifestation of the salt problem is elevated salinity in the San Joaquin River at the point where it enters the Delta; this level is much higher than in the Sacramento River and marginally meets applicable water quality standards for much of the year. At times, salinity from sea water mixing into the western Delta and salinity from the San Joaquin River creates a Delta with a “freshwater corridor” leading from the Sacramento River to the State and federal water export pumps in the south Delta.

Salinity in the Delta Ecosystem

The role of water quality characteristics in ecosystem function, including salinity, temperature, turbidity, and DO, is discussed in detail in Chapter 4. Salinity is a defining characteristic of habitat for estuarine organisms and perhaps the most important water quality characteristic affecting municipal, industrial, and agricultural water use. However, salinity patterns that benefit native species are sometimes in conflict with human uses of water.

The salinity tolerances and preferences of fish vary by species. Delta smelt spawn in fresh water, but juveniles and adults generally show a preference for salinity in the range of 0.5 to 5 parts per thousand (ppt). Adult longfin smelt tolerate a much wider range of salinity and thrive in salinities greater than 5 ppt. Splittail do well in a wide range of salinities from fresh water up to 18 ppt (Moyle 2002). Largemouth bass and bluegill, introduced species, prefer fresh water and are rarely found at salinities greater than 1 to 2 ppt. The location, extent, and dynamics of the freshwater-saltwater interface in the Bay-Delta is an important factor in the distribution and abundance of many fish, invertebrate, and plant species, and is largely determined by the amount of fresh water flowing from the Delta west into Suisun Bay.

The interface between fresh water and salt water is a critical region of the estuary for many native fish and other organisms. Although there is no broadly accepted definition, the low salinity zone (LSZ) of the estuary is generally considered to be the region with salinity ranging from fresh water up to about 5 ppt, about one-seventh the salinity of sea water. The part of the salinity gradient centered on 2 ppt is considered to be of particular importance because it is hypothesized to be an area where suspended particulate matter and organisms accumulate. The location in the Bay-Delta where the tidally averaged salinity at 1 meter from the bottom is 2 ppt is known as X2 (measured as distance in kilometers from the Golden Gate Bridge) and serves as a water quality objective to regulate Delta outflow. The endangered Delta smelt show a preference for the LSZ. Their distribution during most of the year is centered near X2 (Nobriga et al. 2008). The position of X2 is also correlated with the abundance of several estuarine fish and invertebrates such as the bay shrimp and longfin smelt. That is, higher outflows (X2 located closer to the Golden Gate Bridge) are correlated with greater abundance of longfin smelt and bay shrimp (Kimmerer 2004). However, the processes linking greater Delta outflow with the abundance of estuarine species in the Bay-Delta system are not clearly understood, and continue to be studied and debated.

One proposed mechanism for the benefits of X2 as a regulatory marker for Delta smelt and other pelagic species is its relationship to the extent of low-salinity habitat. Lower values of X2 place it in the vicinity of Grizzly and Suisun bays, which results in a much larger area of low-salinity habitat than when X2 is located upstream of the confluence of the Sacramento and San Joaquin rivers. One of the potential negative effects of climate change will be a reduction in the availability of suitable low-salinity habitat for Delta smelt. The combined effects of sea level rise and changes in other aspects of estuarine habitat caused by climate change and increased water diversions are likely to pose a significant threat to the future survival of Delta smelt (Feyrer et al. 2011). Additional information on the relationship between flows in the Delta, the low-salinity zone, and implications for ecosystem health is included in Chapter 4.

Effects of Salinity on Agricultural Water Use

As noted in Chapter 5, agricultural use of water in the Delta is a significant factor in the health of the Delta's regional economy. The effect of salinity on agricultural water use varies by crop, soil type, and other factors (Hoffman 2010). The existing water quality objective, designed to protect the most sensitive crops, is set by the SWRCB at 700 microsiemens per centimeter (μS/cm) during the irrigation season and 1,000 μS/cm for the remainder of the year in southern Delta channels. At 700 μS/cm, water is relatively fresh, approximately equivalent to a salinity of 0.37 ppt (about 1 percent). The SWRCB is reviewing this objective based on the most recent information about the impacts of salinity on typical Delta crops. Salts from upstream and in-Delta agricultural drainage and from seawater intrusion from the Bay can affect agricultural water use in the Delta. Poor flow circulation in some parts of the Delta resulting from water diversions and historical channelization can exacerbate salinity problems.

Water quality to protect agricultural water use in the southern Delta is controlled through a combination of San Joaquin River inflow, export pumping, and Delta outflow changes. When salinity threatens to exceed water quality objectives for the San Joaquin River near Vernalis, additional high-quality water is released from New Melones Reservoir.

The effect of these releases is tempered by the installation and operation of flow barriers in the southern Delta to benefit agriculture. Salinity from seawater intrusion is reduced through a combination of reservoir releases, gate closures, and export pumping changes that, when necessary, control Delta outflow. Any significant changes to the way that water moves into or through the Delta, such as sea level rise, changed conveyance, changed inflow, or changed outflow, will change salinity patterns in the Delta.

Water quality at the SWP and CVP export pumps in the southern Delta, while usually meeting all applicable standards for municipal and agricultural use, is significantly higher in salinity than Sacramento River inflow to the Delta. Allowing salinity to vary in a way that might benefit native species could affect agricultural and municipal uses of Delta water.

Effects of Salinity on Municipal and Industrial Water Uses

Salinity contamination of municipal water supplies, as described in the following section on drinking water quality, can make water unpalatable, contributes to the formation of harmful disinfection byproducts, and increases corrosion of pipes and equipment. The existing objectives for protection of municipal and industrial beneficial uses in the southern Delta, expressed as limits on concentration of chloride, were developed to protect former industrial uses, but have been retained because they also protect drinking water quality. Secondary standards (standards that apply to aesthetic properties) for drinking water supplies also apply to water exported from the Delta by the CVP and SWP.

Under the current salinity regulations and operations practices for Delta water, municipal and industrial water supplies generally meet all salinity objectives. However, sea level rise, Delta levee failures, and increasing salt from upstream all threaten Delta municipal and industrial water supplies. Removing salts from water supplies is technically possible, although difficult and expensive; and disposing of the concentrated salt waste stream remains a key challenge.

Increased salinity further affects the reliability of municipal and industrial water supplies by reducing opportunities for water reuse and recycling (Healey et al. 2008), in turn potentially increasing reliance on imported surface water. Moving Delta intakes upstream, away from the influence of seawater intrusion and San Joaquin River inflow, could substantially reduce these water supply threats and is the subject of analysis under the current Bay Delta Conservation Plan process.

The salinity regime in the Delta is driven by natural flows, water management, and human land and water uses in the Delta and its watershed. Achieving the coequal goals will require updated comprehensive flow objectives and water quality control programs for salinity that balance ecosystem and water supply needs. The SWRCB must pay significant attention to the examination and resolution of these water quality issues in its development of new Delta flow requirements and as new plans for Delta conveyance are developed.

Drinking Water Quality

Water moving through the Delta contributes some part of the drinking water supplies for more than 25 million Californians. It is also used extensively for body-contact recreation such as swimming and water skiing. At the current locations where Delta water is diverted for municipal use, the water sometimes contains relatively high concentrations of bromide, organic carbon, nutrients, and dissolved solids (salinity). These drinking water constituents of concern are not directly harmful in drinking water, but they lead to formation of harmful chemicals during drinking water treatment, or contribute to taste, odor, or other municipal water supply problems. Sources of these drinking water constituents of concern include natural processes, such as tidal mixing of sea water into the Delta, and the flux of water and organic matter from wetlands, as well as urban runoff, agricultural runoff, and municipal wastewater discharge. Pathogenic (infectious) protozoa, bacteria, and viruses are also present in Delta waters and are a disease risk for both drinking water and body-contact recreation.

The future of water quality is a major concern for municipalities using Delta water. Current water quality regulations and policies for surface waters do not directly apply to many of the drinking water quality constituents of concern. Sea level rise, levee failure, salinity variability, agricultural water use, and increased urban runoff due to population growth in the watershed all pose a threat to drinking water quality. Clear policies regarding the protection of water quality relevant to the drinking water quality constituents of concern are needed to prevent such degradation. The Central Valley RWQCB is developing a drinking water policy that is, in part, intended to prevent the degradation of high-quality drinking water sources (Central Valley RWQCB 2010).

Disinfection Byproducts

Treatment of public water supplies is necessary to prevent disease caused by pathogenic organisms. However, bromide and organic carbon in municipal water supplies contribute to the formation of harmful disinfection byproducts when water is treated for domestic use (Healey et al. 2008, AWWA 2011). (See sidebar, Disinfection Byproducts.) The disinfection byproducts of primary concern in tap water, such as trihalomethanes (THMs), haloacetic acids, and bromates, are carcinogens subject to stringent public health standards. Treatment of water from the Delta is particularly challenging because it can contain elevated levels of both bromide and organic carbon (DWR 2007). Changes to drinking water treatment processes to reduce the amounts of disinfection byproducts in tap water are technologically challenging and can significantly increase the cost of drinking water treatment (Chen et al. 2010).

Organic carbon (total or dissolved) is an aggregate measure of the amount of a wide variety of organic compounds in water. In fresh water, these compounds typically come largely from decaying plant material. Along with bromide, elevated concentrations of organic carbon contribute to formation of disinfection byproducts. The amount of disinfection byproduct varies with the type and source of organic carbon, but total organic carbon concentration is nearly always correlated with disinfection byproduct formation. Large-scale restoration of wetlands could increase the amount of disinfection byproducts formed in Delta

DISINFECTION BYPRODUCTS

Disinfection byproducts are formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter (decaying vegetation) present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts identified in drinking water include THMs, haloacetic acids, and bromates. The USEPA has established regulations for these contaminants and set the maximum contaminant levels (MCLs) to prevent health effects (40 *Code of Federal Regulations* Part 141).

Trihalomethanes (THM) are a group of four chemicals formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. The THMs are chloroform, bromodichloromethane, dibromochloromethane, and bromoform. THM violations are the primary difficulty for drinking water systems that use water from the Delta, especially the smaller systems. Some people who drink water containing total THMs in excess of the MCL over many years could experience liver, kidney, or central nervous system problems and increased risk of cancer.

Haloacetic acids are a group of chemicals formed along with other disinfection byproducts when chlorine or other disinfectants used to control microbial contaminants in drinking water react with naturally occurring organic and inorganic matter in water. Haloacetic acids include monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid. Some people who drink water containing haloacetic acids in excess of the MCL over many years may have an increased risk of cancer.

Bromate is a chemical formed when ozone used to disinfect drinking water reacts with bromide in source water. Bromate formation is a problem for drinking water systems that use ozone as the primary disinfectant. Bromate violations are uncommon, but are a concern during low-flow years when seawater intrusion causes bromide concentrations in Delta water to increase. Some people who drink water containing bromate in excess of the MCL over many years may have an increased risk of cancer.

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water used for municipal supplies due to an increased amount of total organic carbon and the greater disinfection byproduct formation potential of wetland-derived organic carbon (Kraus et al. 2008).

Salinity

Salinity, frequently measured as electrical conductivity or total dissolved solids, has several significant effects on the use of water for domestic uses. Salts make water unpalatable at relatively low concentrations, with 500 parts per million total dissolved solids set as the recommended maximum level in the California secondary drinking water standards (California Code of Regulations, Title 22, section 64449). Salinity also increases the cost of treatment and costs to the consumer due to corrosion and other factors (Howitt et al. 2009). One common component of sea water, bromide, is a disinfection byproduct precursor that forms THMs and haloacetic acids with chlorine or chloramine disinfection, and forms bromate with ozone disinfection.

Pathogens

Pathogenic organisms and pathogen indicators are found in most surface waters. Two common protozoan pathogens that cause gastroenteritis, *Giardia lamblia* and *Cryptosporidium parvum*, have been found in Delta waters (at generally low levels) with respect to drinking water sources or body-contact recreation (Tetra Tech 2007). Source waters that exceed drinking water regulatory thresholds for *Cryptosporidium* trigger additional pathogen removal requirements (USEPA 2004). Although available data do not demonstrate that such conditions currently exist at Delta municipal water supply intakes, future plans that move or create new water intakes could result in increased treatment costs. Pathogen indicators such as fecal coliforms or *E. coli* are frequently at levels of concern in urban stormwater runoff. Several urban creeks and Delta water bodies that receive urban runoff are listed as impaired due to the presence of these indicator bacteria.

Nutrients

In the Delta, drinking water supplies with excessive levels of nutrients are primarily of concern because they, along with other factors such as residence time and temperature, can stimulate algae growth in the Delta and in reservoirs (Tetra Tech 2006a, Izaguirre and Taylor 2007). Algal blooms in storage reservoirs can disrupt treatment processes, and cause taste and odor problems. Taste and odor complaints associated with Delta water supplies have been attributed to algae growth in reservoirs or in the Delta itself (DWR 2007).

Drinking Water Intakes

The quality of Delta water with respect to drinking water use varies considerably both geographically and over time. Average organic carbon and bromide concentrations are very low in the Sacramento River where it enters the Delta. San Joaquin River water is moderately high in bromide, salinity, and nutrients, and moderately high in organic carbon. Intakes in the west Delta can be strongly influenced by the estuarine salinity gradient. An intake for the City of Antioch is frequently out of use because of salinity intrusions. The North Bay Aqueduct intake on Barker Slough in the northwest Delta is strongly affected by the local watershed and has the highest average organic carbon concentrations of any Delta municipal water supply intake (Tetra Tech 2006b). In addition to the drinking water quality problems at the current North Bay Aqueduct intake location, the intake may also have a negative effect on the ecosystem because it is located in an area that is otherwise high-quality habitat for listed native fish species.

Groundwater Quality Concerns

The drinking water supply from groundwater for many communities in the Delta and areas served by water exported from the Delta is contaminated by nitrates and other pollutants, particularly in the San Joaquin Valley. Survey findings show that a high financial burden is borne by low-income households when it comes to nitrate-contaminated water

(Pacific Institute 2011). The high cost of accessing water from alternative sources, coupled with the low earnings of these households, often makes safe drinking water in these communities unaffordable (Pacific Institute 2011). Small community and private water systems throughout the Central Valley and in the Delta rely on groundwater as their primary source of drinking water. They are affected by groundwater contamination to a greater degree than larger public water systems because many are in areas that are vulnerable to contamination (SWRCB 2011). Their wells are often shallower than larger community systems, and they have limited resources to treat or respond to contaminated groundwater problems. The California Legislature explicitly recognized these issues when, in 2012, it enacted Assembly Bill 685, declaring the established State policy that "every human being has the right to safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitary purposes" (Water Code section 106.3(a)). More information on groundwater and how it relates to the Delta can be found in Chapter 3.

Environmental Water Quality

The Delta ecosystem is affected by a variety of pollutants discharged into Delta and tributary waters. Pollutants of concern affecting Delta biological species and ecosystem processes include nutrients, pesticides, mercury, selenium, and other persistent bioaccumulative toxic substances. Newly identified pollutants of potential concern (often referred to as emerging contaminants) also need to be investigated.

Nutrients

Nutrients, and their potential benefits and problems, have become an increasingly important component in the discussion of water quality issues in the Delta. The role of nutrients and nutrient loading for the Delta and Suisun Marsh is a subject of debate. Plant nutrients of concern in water are primarily nitrogen and phosphorus compounds including ammonia, ammonium, nitrite, nitrate, and phosphate. Excessive amounts (over fertilization) or altered proportions of these nutrients in streams, rivers, lakes, estuaries, or the coastal ocean can have detrimental effects on ecosystems. Die-offs of algae that deplete oxygen and cause fish kills are a well-known example, but even less obvious effects of nutrients can have important impacts on aquatic ecosystems. Changes in the types of algae that form the base of the aquatic food web, including growth of toxic algae, have been linked to excessive amounts or altered ratios of plant nutrients. Recent and current research is reconsidering the role of nutrients for aquatic ecosystems of the Delta, as follows:

- **Ammonium.** Ammonium in Delta waters has been shown to affect ecosystem water quality. Dugdale et al. (2007) has determined that ammonium concentrations may be having a significant impact on phytoplankton composition and open-water food webs because of suppression of diatom blooms in the Bay-Delta. Ammonium concentrations in Suisun Bay and the Delta have been increasing, primarily due to point source discharge loading from wastewater treatment facilities. It is not known, however, how much this inhibition extends to freshwater algae in the Delta.
- **Nutrient ratios.** Ratios of nutrients in Delta waters are thought to be a primary driver in the composition of aquatic food webs in the Bay-Delta (Glibert et al. 2011). The effect of ammonium on food webs in the Delta remains an open question, and much active research and healthy scientific debate continue.

- **Harmful algal blooms.** HABs create a toxic environment for aquatic organisms and the organisms that eat them. The emergence of HABs over the past decade threatens environmental water quality. The shift toward greater abundance of cyanobacteria in the Delta includes known HABs such as *Microcystis aeruginosa*. *Microcystis aeruginosa* has become a common bloom-forming component of the phytoplankton of the Delta during the warm summer and early fall months (Lehman et al. 2005, 2008). Interactions between nutrients and HABs in the Delta warrant additional study and are currently being investigated.
- **Nonnative aquatic plants.** Nutrients affect the productivity of aquatic macrophytes (plants visible to the naked eye) and the structure of the aquatic plant community (Wetzel 2001). Two nonnative aquatic plants, Brazilian waterweed and water hyacinth, have become particularly problematic in the Delta. Scientific studies have documented the distribution and spread of these invasive aquatic plants in the Delta (Underwood et al. 2006, Hestir et al. 2008, Khanna et al. 2011, Santos et al. 2011). The role of nutrient enrichment in the spread and productivity of these nonnative aquatic plants is unknown. Further research is required on the potential links between invasive aquatic plants in the Delta and nutrient inputs.

The effects of increased nutrient inputs also need to be considered in light of anticipated changes in the Delta with regard to lowered turbidity and warming temperatures. Figure 6-2 shows increasing nutrients in the Delta over time. As discussed in the following section, nutrients have been implicated in DO depletion in Delta channels due to the stimulation of plant growth with subsequent death and decay, and the microbial conversion of total ammonia to nitrate through the process of nitrification.

Dissolved Oxygen

DO in water is essential to the survival of most fish and many other aquatic organisms. Depletion of DO in a water body because of decaying organic matter is a classic water quality problem that can result in clear signs of pollution, including fish kills and foul odors. Low DO concentrations also can have less obvious effects. DO events occur regularly in the channels of Suisun Marsh and the Stockton Deep Water Ship Channel (SDWSC) and sporadically elsewhere in the Delta, with several waterways listed as impaired by the RWQCB.

One of the most significant water quality issues affecting the Delta in recent decades has been low DO episodes (DO concentrations less than regulatory objectives) in the SDWSC reach of the San Joaquin River in the Delta, which were thought to act as a barrier to salmon migration (Central Valley RWQCB 2005). Until the last few years, low DO events were a regular occurrence in this part of the Delta primarily during the summer and fall months.

The SDWSC DO problem has existed since at least the 1960s. The Central Valley RWQCB added this segment of the Delta to its list of impaired water bodies in 1998, and adopted a TMDL in 2005 that follows a phased approach requiring studies and initial actions followed by reconsideration of TMDL requirements in 2012. Extensive studies have identified several contributing factors, including inputs of algae from upstream (probably related to nutrient loads), discharges of total ammonia from the Stockton Regional Wastewater Control Facility (RWCF), increased channel depth due to dredging, and reduced net flows (Central Valley RWQCB 2005). See sidebar, Applying Adaptive Management in Water Quality Decisions, for more information about an adaptive management approach to DO in the SDWSC.

The improved wastewater treatment processes at the RWCF were fully operational starting in 2006. This, along with other discharge reductions upstream, appears to have greatly reduced the frequency and severity of low DO episodes in the SDWSC. The California Department of Water Resources (DWR) aeration facility also has been shown to be an effective remedy for the occasional DO depletion problem that might occur under current conditions. The actions taken to

Nutrients Create Delta Water Problems

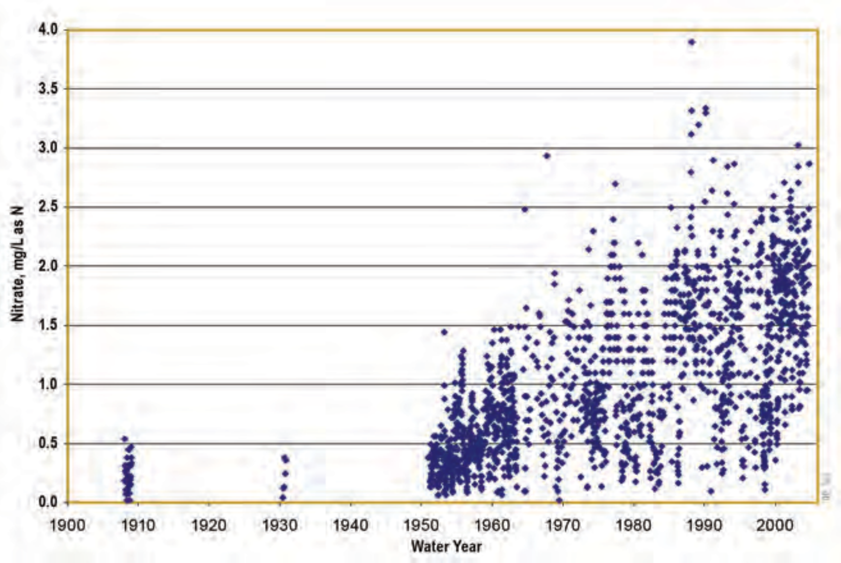

Figure 6-2

Nitrate concentrations at the point where the San Joaquin River enters the Delta dating back to 1908 show how much this important plant nutrient has increased. High nutrient concentrations are linked to a variety of problems including DO depletion, growth of nuisance aquatic plants, and taste and odor problems in drinking water.

Source: Adapted by the Delta Stewardship Council with data provided by USGS

comply with the current TMDL, along with improved flows and load reductions in the San Joaquin River watershed, appear to have provided a solution to this longstanding water quality problem. If continued, the actions taken to comply with the SDWSC TMDL should be sufficient to prevent future DO depletion problems.

The DO depletion problems in Suisun Marsh are caused by seasonal operations of ponds and wetlands managed for waterfowl hunting. For most of the year, duck club ponds are drained and occasionally flooded to promote the growth of plants that are the favored food of water fowl. When these ponds are flooded for hunting in the late summer and fall, the decay of accumulated plant matter followed by tidal exchanges of water with adjoining channels can cause severe DO depletion. Some of these low DO events have caused documented fish kills. The San Francisco Bay RWQCB has started the TMDL process to address DO depletion in Suisun Marsh.

The best pathways to address other Delta low DO problems will vary with local conditions and causes, but likely will be a combination of reduced loadings of oxygen-demanding substances and changes to flow conditions, under the framework of adaptive management. As TMDLs are developed to address low DO concentrations in the Delta, actions needed to improve DO conditions will be implemented through SWRCB and RWQCB programs, including NPDES permits, stormwater NPDES permits, WDRs, waivers of WDRs, and water rights. Low DO conditions in the Delta need to be addressed to prevent these conditions from increasing in extent and severity.

Applying Adaptive Management in Water Quality Decisions

An adaptive management approach to water quality control decisions should be taken to plan for and assess their outcomes. The following is an example of how the Council's three-stage, nine-step adaptive management framework (see Appendix C) was used for water quality decision making in the TMDL process to improve DO concentrations in the SDWSC.

Adaptive Management Step			Improving DO Concentrations in the SDWSC
Plan	1	Define/redefine the problem	Low concentrations of DO in the SDWSC periodically exceeded the Central Valley Basin Plan water quality objectives for DO for many years. Low DO acted as a barrier to migrating salmon.
	2	Establish goals, objectives, and performance measures	**Goal:** Meet the water quality objectives for DO in the SDWSC. **Objectives:** Maintain minimum DO concentrations of 5 milligrams per liter (mg/L) at all times and 6 mg/L September through November.
	3	Model linkages between objectives and proposed action(s)	Hydrodynamic and water quality models informed the development of a Physical and Chemical Processes Conceptual Model and a Biological and Ecological Effects Conceptual Model. The models identified at least four primary factors or processes influencing oxygen concentrations: (1) San Joaquin River flow through the SDWSC, (2) SDWSC volume, (3) algae and oxygen-demanding substances from the San Joaquin River upstream of the SDWSC, and (4) oxygen-demanding substances, including ammonia discharged from the RWCF. http://www.sjrdotmdl.org/concept_model/index.htm
	4	Select action(s) (research, pilot, or full-scale) and develop performance measures	**Selected Actions:** (1) Conduct studies to identify causes for the low DO levels and assign responsibility to correct the problem; (2) reduce RWCF ammonia discharges to the San Joaquin River; and (3) construct a Demonstration Dissolved Oxygen Aeration Facility (Aeration Facility). **Performance Measures:** ▪ Administrative – Implement Phase 1 TMDL actions. ▪ Output – Implement studies; select wastewater treatment improvements to reduce ammonia discharges including engineered wetlands and nitrifying bio-towers; develop pilot-scale aeration project. ▪ Outcome – DO concentrations are maintained at or above the water quality objectives for DO. Aquatic life, including resident and migratory fish, is not affected by low DO conditions.
Do	5	Design and implement action(s)	**Selected Actions:** (1) Conduct ongoing studies to improve the conceptual models; (2) add engineered wetlands and two nitrifying bio-towers to the RWCF; and (3) design, build, and operate the Aeration Facility at Rough and Ready Island to determine its applicability for increasing DO concentrations in the SDWSC.
	6	Design and implement monitoring plan	Collect baseline DO data prior to aerator operations. Conduct ongoing studies to test the understanding of linkages in the conceptual models. Conduct compliance monitoring at the RWCF as required by the permit. Conduct performance monitoring of the Aeration Facility to measure achievement of the target (increased DO concentrations in the SDWSC).
Evaluate and Respond	7	Analyze, synthesize, and evaluate	Technical Working Group will assess the study results and aeration pilot-study results.
	8	Communicate current understanding	Technical reports, study results, and web-based conceptual models were developed and maintained on a website. Pilot Report Aeration System and staff presentation to the Central Valley RWQCB (February 3, 2011).
	9	Adapt	Development of a revised control program (Phase 2 TMDL) including identification of additional or modified actions. Development of an aeration agreement with long-term funding for operation and maintenance of the Aeration Facility, including possible future modifications. Development of a system-level (long-term) monitoring plan for the Aeration Facility. Periodic review of control program actions and aerator operations.

Pesticides

Pesticides include insecticides, herbicides, fungicides, and various other substances used to control pests. In the Bay-Delta region, the primary pesticides of concern include the organophosphorus pesticides (for example, diazinon and chlorpyrifos), pyrethroid insecticides, and the legacy organochlorine pesticides (for example, DDT, chlordane, and dieldrin). These substances are known to have adverse impacts on aquatic organisms or, in some cases (as with the organochlorine pesticides), birds and mammals.

The Sacramento, San Joaquin, and Feather rivers; the Delta; and numerous agriculturally dominated streams in the Central Valley are either listed as impaired or are covered under an existing TMDL for pesticides (Central Valley RWQCB 1998, 2006). Delta waterways were placed on the CWA section 303(d) list for diazinon and chlorpyrifos due to aquatic toxicity (SWRCB 2010).

Smaller agriculturally dominated waterways and urban creeks are particularly vulnerable to toxicity from pesticides. Although agriculture is considered the primary source of pesticide impairment in the Central Valley and Delta, urban sources are also locally important (Kuivila and Hladik 2008). Some of the highest pesticide concentrations have been observed in residential area creeks and waters receiving urban runoff (Weston et al. 2005). Pyrethroid insecticides, which are common replacements for the organophosphorus pesticides, have been implicated as the principal pesticides causing toxicity in surface water samples collected from throughout California (Hunt et al. 2010).

Aquatic invertebrates in the water column are the organisms most affected by chlorpyrifos and diazinon exposure (Giddings et al. 2000); however, pyrethroids—because of their high potential to stick to organic matter—also can affect sediment-dwelling organisms (Werner and Oram 2008, Weston et al. 2004). Pyrethroid pesticides from multiple runoff sources have been found at levels toxic to aquatic invertebrates (Weston et al. 2005, Weston 2010).

Contaminants cannot be eliminated as a possible contributor to the declines in open-water fish populations in the Delta (known as pelagic organism decline [POD]). Johnson et al. (2010) reported that insufficient data are available to determine whether contaminants played an important role in the POD. Research on the role of contaminants in the POD continues with efforts under way to better define the presence of contaminants in the environment, the effects of contaminant mixtures, sublethal effects of contaminants on the POD species, and the effects of contaminants on prey organisms (Baxter et al. 2010). Synergistic effects of pesticide mixtures have been demonstrated for other species including juvenile salmon (Laetz et al. 2009).

Mercury

The Delta and many Delta tributaries are included in the SWRCB's section 303(d) list of impaired water bodies due to mercury contamination (Central Valley RWQCB 2009). Historical mercury mining in California's Coast Ranges and mercury use associated with gold mining in the Sierra Nevada over a century ago have left an environmental legacy of pervasive mercury contamination in many Northern California watersheds (Alpers and Hunerlach 2000). The current regulatory approach for mercury includes the mercury TMDL adopted by the San Francisco Bay RWQCB in 2006 and the Delta methylmercury TMDL adopted by the Central Valley RWQCB in 2010. Unfortunately, however, mercury is likely to persist in California's environment for many years to come.

Mercury is transformed into methylmercury by bacteria in the environment. Methylmercury, initially present at very low concentrations, enters the aquatic food web and can accumulate to levels of concern in long-lived fish at the top of the aquatic food chain, such as striped bass and largemouth bass. Methylmercury has been found in some types of Delta fish at concentrations that may be harmful to human health. The State has issued health advisories for fish consumption due to mercury contamination for a number of water bodies in the Delta and its watersheds. Mercury contamination of fish is of particular concern for people who are frequent consumers of Delta fish (Shilling 2009).

There is general concern that increased concentrations of methylmercury in water, sediment, and plants and animals might result from restoration of wetland and floodplain habitats in the Delta and, thus, must be carefully planned and monitored to minimize the production of methylmercury. For instance, the restoration of wetlands, particularly in areas where the abundance of mercury in soils or sediments is elevated, could accelerate the production of methylmercury and increase the contamination of aquatic plants and animals (Naimo et al. 2000, Wiener and Shields 2000). Additionally, flooding of wetlands or uplands, or fluctuating water levels during tidal cycles could stimulate methylmercury production and transport, thereby increasing concentrations of methylmercury in water and in plants and animals (Hecky et al. 1991, Hall et al. 1998, Paterson et al. 1998, Bodaly and Fudge 1999). Increased methylmercury production is a significant concern for planned wetland and floodplain ecosystem restoration projects, and should be monitored.

Further study is needed to determine the dominant processes affecting methylmercury concentrations in food webs in the Delta. The CALFED Ecosystem Restoration Program developed a framework (Mercury Strategy) for monitoring, research, risk communication, and adaptive management to address mercury problems in the Bay-Delta system (Wiener et al. 2003). The approach taken by the Central Valley RWQCB in its Delta Mercury Control Program, adopted April 22, 2010, is consistent with the Mercury Strategy (Central Valley RWQCB 2010).

Selenium

Selenium, a naturally occurring element, is an essential nutrient at low concentrations for humans and other organisms. However, higher concentrations can be toxic to fish and wildlife. Once selenium enters the aquatic environment, it has a high potential to bioaccumulate in zooplankton and benthic (bottom-dwelling) invertebrates and, subsequently, to biomagnify in the food web as it reaches top-level predators such as fish, birds, and mammals (Skorupa and Ohlendorf 1991, Fan et al. 2002, Hamilton 2004, Stewart et al. 2004, Paveglio and Kilbride 2007).

The major source of selenium loading to San Francisco Bay is the San Joaquin River, which receives selenium-laden agricultural drainage waters from the western San Joaquin Valley (Luoma and Presser 2000). Other sources of selenium loading include oil refineries, municipal and industrial wastewater, urban and nonurban runoff, atmospheric deposition, and erosion and sediment transport from within the north San Francisco Bay. Improved wastewater treatment at petroleum refineries discharging into San Francisco Bay has reduced the amount of selenium discharged, but these facilities are still the most significant point source of this pollutant (San Francisco Bay RWQCB 2011b).

Recent monitoring results indicate that selenium water column concentrations in the north San Francisco Bay are much lower than the current 5-parts per billion objective for chronic exposure (San Francisco Bay RWQCB 2011b). However, levels of selenium in aquatic organisms and fish show that the current regulatory criteria may not be sufficient. Despite progress to reduce selenium in the Bay-Delta system, levels in the food chain are still of concern. Selenium has been identified as a possible contributing factor to the observed decline of white sturgeon, Sacramento splittail, starry flounder, and diving ducks such as surf scoters. The focus of regulatory efforts at the State and national level is shifting from water-column concentrations to the concentration of selenium in the tissues of affected organisms (San Francisco Bay RWQCB 2011b).

Historically, portions of the San Joaquin River downstream of Grasslands, Salt Slough, and Mud Slough contained elevated levels of selenium from agricultural drainage (Saiki et al. 1993). The discharge of selenium from this area also has been significantly reduced from historical levels under a control program administered by Central Valley RWQCB, with plans for further reductions through 2019 (Reclamation 2009).

Contaminants of Emerging Concern

The term "contaminants of emerging concern" refers to a broad class of largely unregulated compounds for which there is concern that adverse effects might occur at environmentally significant concentrations. Examples of manufactured chemicals frequently found in water bodies and organisms include flame retardants, pesticides, human and veterinary pharmaceuticals, and ingredients in personal care products (Kolpin et al. 2002, Daughton 2004, Hoenicke et al. 2007).

Contaminants of emerging concern include many manufactured chemicals. These manufactured chemicals have the potential to alter water quality because of their widespread use, pathways to the environment, and potency. The primary sources for most contaminants of emerging concern include effluent from wastewater treatment plants, agricultural fields, and stormwater runoff. Many chemicals identified as contaminants of emerging concern have not been tested for their potential toxic effects on aquatic life. Most emerging pollutant maximum concentrations in the environment are well below established lethal concentration values for even the most sensitive aquatic species. Sublethal and chronic low-level exposures are of primary concern (Oros 2003, Brander et al. 2009, Ostrach 2009).

Regulatory and chemical monitoring programs should adapt to the quickly changing mix of contaminants of emerging concern identified through current studies and the peer-reviewed scientific literature (best available science). Effective management of contaminants of emerging concern in the Delta will require responsible agencies to perform appropriate scanning-level activities to prioritize a specific list of pollutants of highest concern and to develop or require work plans for special studies, and to conduct or require monitoring in accordance with the work plans. To this end, in 2011, the SWRCB established a Science Advisory Panel to address contaminants of emerging concern in aquatic ecosystems. The panel completed a report in April 2012 that included several recommendations for how the SWRCB should monitor and assess potential impacts of contaminants of emerging concern (Anderson et al. 2012).

POLICIES AND RECOMMENDATIONS

Policies and recommendations to address the water quality issues discussed in the preceding sections are based on the following strategies:

- Require Delta-specific water quality protection
- Protect beneficial uses by managing salinity
- Improve drinking water quality
- Improve environmental water quality

These major aspects of water quality are critical to achieving the coequal goals. The approach described here includes augmenting or accelerating existing programs where it is feasible to address an existing or anticipated water quality problem. The SWRCB and RWQCBs have broad authority to protect and regulate water quality; therefore, this chapter sets forth priority Delta-specific recommendations and does not contain regulatory policies at this time.

Require Delta-specific Water Quality Protection

Water flow, water quality, water supply, and habitat conditions in the Delta are distinctly different from other parts of the watershed and from San Francisco Bay downstream. The Delta is the most valuable estuary and wetland ecosystem on the West Coast of North and South America (Water Code section 85002), and is the primary habitat for a number of special-status species. Many communities in and around the Delta draw their drinking water directly from Delta waterways. Delta waterways also receive urban stormwater, treated wastewater, agricultural drainage, and drainage from managed wetlands. Studies have shown that such discharges can have significant impacts on water quality. These impacts are often more severe near the point of discharge. Stormwater, wastewater, and agricultural drainage discharges into the Delta should be managed so that they do not pose a significant risk to the beneficial uses of water in the Delta.

Problem Statement

Water quality management approaches developed for general application statewide or in other regions may not be sufficient for the unique and dynamic conditions of the Delta, its biological resources, and critical water supply services. Water supplies and habitats for special-status species require proactive and anticipatory measures for water quality protection consistent with their importance in achieving the coequal goals.

Policies

No policies with regulatory effect are included in this section.

Recommendations

WQ R1. Protect Beneficial Uses

Water quality in the Delta should be maintained at a level that supports, enhances, and protects beneficial uses identified in the applicable State Water Resources Control Board or regional water quality control board water quality control plans.

WQ R2. Identify Covered Action Impacts

Covered actions should identify any significant impacts to water quality.

WQ R3. Special Water Quality Protections for the Delta

The State Water Resources Control Board or regional water quality control board should evaluate and, if appropriate, propose special water quality protections for priority habitat restoration areas identified in recommendation ER R2 or other areas of the Delta where new or increased discharges of pollutants could adversely impact beneficial uses.

Protect Beneficial Uses by Managing Salinity

Beneficial uses within the Delta include drinking water, agriculture, and ecosystem protection. Salinity potentially affects these uses, but to varying degrees. The primary sources of salinity in the Delta are from tidal seawater intrusion from the Pacific Ocean through the San Francisco Bay, and to a lesser extent from agricultural and other discharges in the Central Valley. Historically, natural flows through the Delta regulated salinity in a way that favored the Delta ecosystem. Today, salinity in the Delta is dominated by the effects of upstream water diversions and use of the Delta to convey flows to Central and Southern California. The SWRCB is responsible for ensuring protection of beneficial uses through regulation of pollutant discharges, and regulation of water diversions and flows under their water rights authority.

Problem Statement

Salinity affects Delta agricultural, municipal, and environmental beneficial uses, but in different ways. Salinity and flow conditions in the Delta are affecting ecosystem, agricultural, and municipal uses. The timing and distribution of salinity is primarily affected by flow, which is largely determined by water management in the Delta and its watersheds as determined by applicable flow objectives. Delta conditions have changed since the current Delta flow objectives were adopted, and new scientific information about salinity, flow, and their effects on beneficial uses is available.

Policies

ER P1 in Chapter 4 on the SWRCB's Delta Flow Objectives addresses this issue.

Recommendations

ER R1 in Chapter 4 on the SWRCB's Update of Delta Flow Objectives addresses this issue.

Improve Drinking Water Quality

Millions of Californians entirely or partially rely on the Delta as a drinking water supply, and the future quality of that water supply is uncertain. Contamination of groundwater supplies places greater demand on surface waters that are tributary to the Delta for urban and agricultural users. Current water quality regulations and policies for surface waters do not apply directly to many of the drinking water quality constituents of concern. Sea level rise, levee failure, salinity variability, agricultural water use, and increased urban runoff from population growth in the watershed all pose a threat to drinking water quality. To prevent such degradation, we need clear policies regarding the protection of water quality relevant to the drinking water quality constituents of concern. The Central Valley RWQCB's anticipated drinking water policy is intended, in part, to prevent the degradation of high-quality drinking water sources (Central Valley RWQCB 2010).

In 2006, the SWRCB, the Central Valley RWQCB, and stakeholders began a joint effort to address salinity and nitrate problems in California's Central Valley and adopt long-term solutions that will lead to enhanced water quality and economic sustainability. Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) is a collaborative basin planning effort aimed at developing and implementing a comprehensive salinity and nitrate management program.

Problem Statement

Delta drinking water supplies are degraded by inputs from sea water, regional soils, and sediments; from agricultural, urban, and industrial sources from the watershed; and from in-Delta sources.

Policies

No policies with regulatory effect are included in this section.

Recommendations

WQ R4. Complete Central Valley Drinking Water Policy

The Central Valley Regional Water Quality Control Board should complete the Central Valley Drinking Water Policy by July 2013.

WQ R5. Complete North Bay Aqueduct Alternative Intake Project

The California Department of Water Resources should complete the North Bay Aqueduct Alternate Intake Project Environmental Impact Report by December 31, 2012, and begin construction as soon as possible thereafter.

WQ R6. Protect Groundwater Beneficial Uses

The State Water Resources Control Board should complete development of a Strategic Workplan for protection of groundwater beneficial uses, including groundwater use for drinking water, by December 31, 2012.

WQ R7. Participation in CV-SALTS

The State Water Resources Control Board and Central Valley Regional Water Quality Control Board should consider requiring participation by all relevant water users that are supplied water from the Delta or the Delta watershed or discharge wastewater to the Delta or the Delta watershed to participate in the Central Valley Salinity Alternatives for Long-Term Sustainability Program.

Improve Environmental Water Quality

A variety of pollutants are discharged into Delta and tributary waters. These pollutants affect Delta biological species and ecosystem processes. Pollutants of concern include nutrients, pesticides, mercury, selenium, and other persistent bioaccumulative toxic substances. Newly identified pollutants of potential concern (emerging contaminants) also need to be investigated.

Problem Statement

Pollutants contained in municipal, industrial, agricultural, other nonpoint source discharges, and legacy sources flowing into the Delta and its tributary waterways, including pollutants that bioaccumulate and biomagnify in the food web, impair the Delta ecosystem. Evidence from water quality and ecosystem monitoring continues to show that significant water pollution problems persist in the Bay-Delta system and the Central Valley. Insufficient funding and support could lead to slowing or even erminating the SWRCB and the San Francisco Bay and Central Valley RWQCBs' engagements in regulatory processes, research, and monitoring that are essential to improving water quality in the Delta.

Policies

No policies with regulatory effect are included in this section.

Recommendations

WQ R8. Completion of Regulatory Processes, Research, and Monitoring for Water Quality Improvement

The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards are currently engaged in regulatory processes, research, and monitoring essential to improving water quality in the Delta. In order to achieve the coequal goals, it is essential that these ongoing efforts be completed and, if possible, accelerated, and that the Legislature and Governor devote sufficient funding to make this possible. The Delta Stewardship Council specifically recommends that:

- *The State Water Resources Control Board should complete development of the proposed policy for nutrients for inland surface waters of the State of California by January 1, 2014.*
- *The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards should prepare and begin implementation of a study plan for the development of objectives for nutrients in the Delta and Suisun Marsh by January 1, 2014. Studies needed for development of Delta and Suisun Marsh nutrient objectives should be completed by January 1, 2016. The water boards should adopt and begin implementation of nutrient objectives, either narrative or numeric, where appropriate, for the Delta and Suisun Marsh by January 1, 2018.*
- *The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should complete the Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for diazinon and chlorpyrifos by January 1, 2013.*
- *The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should prioritize and accelerate the completion of the Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for pyrethroids by January 1, 2016.*
- *The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards have completed Total Maximum Daily Load and Basin Plan Amendments for methylmercury, and efforts to support their implementation should be coordinated. Parties identified as responsible for current methylmercury loads or proponents of projects that may increase*

methylmercury loading in the Delta or Suisun Marsh should participate in control studies or implement site-specific study plans that evaluate practices to minimize methylmercury discharges. The Central Valley Regional Water Quality Control Board should review these control studies by December 31, 2018 and determine control measures for implementation starting in 2020.

WQ R9. Implement Delta Regional Monitoring Program

The State Water Resources Control Board and Regional Water Quality Control Boards should work collaboratively with the California Department of Water Resources, California Department of Fish and Wildlife, and other agencies and entities that monitor water quality in the Delta to develop and implement a Delta Regional Monitoring Program that will be responsible for coordinating monitoring efforts so Delta conditions can be efficiently assessed and reported on a regular basis.

WQ R10. Evaluate Wastewater Recycling, Reuse, or Treatment

The Central Valley Regional Water Quality Control Board, consistent with existing water quality control plan policies and water rights law, should require responsible entities that discharge wastewater treatment plant effluent or urban runoff to Delta waters to evaluate whether all or a portion of the discharge can be recycled, otherwise used, or treated in order to reduce contaminant loads to the Delta by January 1, 2014.

WQ R11. Manage Dissolved Oxygen in Stockton Ship Channel

The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should complete Phase 2 of the Total Maximum Daily Load and Basin Plan Amendment for dissolved oxygen in the Stockton Deep Water Ship Channel by January 1, 2015.

WQ R12. Manage Dissolved Oxygen in Suisun Marsh

The State Water Resources Control Board and the San Francisco Bay Regional Water Quality Control Board should complete the Total Maximum Daily Load and Basin Plan Amendment for dissolved oxygen in Suisun Marsh wetlands by January 1, 2014.

Timeline for Implementing Policies and Recommendations

Figure 6-3 lays out a timeline for implementing the policies and recommendations described in the previous section. The timeline emphasizes near-term and intermediate-term actions.

Timeline for Implementing Policies and Recommendations

TIMELINE

CHAPTER 6: Improve Water Quality

	ACTION (REFERENCE #)	LEAD AGENCY(IES)	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025
RECOMMENDATIONS	Protect beneficial uses (WQ R1)	Varies	●	●
	Identify covered action impacts (WQ R2)	Varies	●	●
	Special water quality protections for the Delta (WQ R3)	SWRCB, RWQCB	●	
	Complete Central Valley drinking water policy (WQ R4)	Central Valley RWQCB	●	
	Complete North Bay Aqueduct Alternative Intake Project (WQ R5)	DWR	●	
	Protect groundwater beneficial uses (WQ R6)	SWRCB	●	
	Participation in CV-SALTS* (WQ R7)	SWRCB and Central Valley RWQCB	●	
	Completion of regulatory processes, research, and monitoring for water quality improvements (WQ R8)	SWRCB, San Francisco Bay and Central Valley RWQCBs	●	
	Implement Delta regional monitoring program (WQ R9)	SWRCB and RWQCBs	●	
	Evaluate wastewater recycling, reuse, or treatment (WQ R10)	Central Valley RWQCB	●	
	Manage dissolved oxygen in Stockton Ship Channel (WQ R11)	SWRCB and Central Valley RWQCB	●	
	Manage dissolved oxygen in Suisun Marsh (WQ R12)	SWRCB and San Francisco Bay RWQCB	●	

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*CV-SALTS: Central Valley Salinity Alternatives for Long-Term Sustainability Program

Agency Key: DWR: California Department of Water Resources RWQCB: Regional Water Quality Control Board(s) SWRCB: State Water Resources Control Board

Figure 6-3

Science and Information Needs

Successful management of water quality depends on a well-designed, comprehensive, and consistent system of water quality monitoring. Current Delta water quality monitoring is fragmented among several different agencies and programs. The Central Valley RWQCB has initiated an effort to develop a Delta Regional Monitoring Program that will consolidate and coordinate most of the current monitoring. Developing a coordinated and thorough regional monitoring program is essential to performance measurement and adaptive management in the Delta.

As identified above, a number of outstanding science questions need to be resolved with respect to water quality. Additional study is needed on the following:

- The effects of salinity on introduced and native plant and animal species
- Trends in concentrations of drinking water constituents of concern
- The effects of nutrients on the Delta ecosystem and municipal water supplies
    - The importance of phytoplankton bloom suppression from ammonium
    - The role of nutrient loading on HABs in the Delta
    - Possible linkages between nonnative aquatic plants and nutrient inputs
- Controlling DO depletion
- The effects of the simultaneous presence of multiple pesticides, even at low levels, on species of concern
- The processes contributing to mercury and selenium compounds in food webs and their effects on the ecosystem
- The impacts of pharmaceutical compounds, personal care products, and other emerging contaminants on the ecosystem
- The combined effects of multiple contaminants and water quality conditions on the ecosystem
- Sources and impacts of pathogens on drinking water sources and recreation in the Delta
- An analysis and evaluation of existing water quality models in the Delta
- Fate and transport of water quality contaminants in the Delta

Issues for Future Evaluation and Coordination

Additional areas of interest and concern related to water quality and the Delta may deserve consideration in the development of future Delta Plan updates, including the following:

- **Small and disadvantaged communities:** Ensuring a safe drinking water supply can have a disproportionate cost for small and disadvantaged communities. Delta communities that are small and disadvantaged include Bethel Island, Courtland, Freeport, Hood, Isleton, Locke, and Walnut Grove. There are also small and disadvantaged communities in areas served by water exported from the Delta that are disproportionately impacted by nitrate and other groundwater pollutants. Available options to correct unsafe drinking water conditions include shared services and facilities; consolidation of several small systems into a single, larger system; centralized treatment; interim point-of-use treatment or use of bottled water; replacement of a contaminated source with an uncontaminated source; and, in the case of chemical contamination, blending of contaminated sources with uncontaminated sources. Consideration also must be given to the new State policy that "every human being has the right to safe, clean, affordable and accessible water adequate for human consumption, cooking, and sanitary purposes" (Water Code section 106.3(a)). Availability and prioritization of funding, restructuring of regulatory requirements, and provision of technical assistance may all be part of the solution, but involve the authority of various agencies including the California Department of Public Health, SWRCB, DWR, U.S. Department of Agriculture, and local cities and counties. An integrated effort including the input and involvement of the regulatory and affected agencies will be needed to properly address these issues and to refine effective recommendations.

- **Coordinated and prioritized water quality monitoring and modeling:** Various water quality monitoring and modeling efforts are ongoing, but are not coordinated among affected agencies. Agencies involved in these efforts include the SWRCB, RWQCBs, DWR, the Interagency Ecological Program, California Department of Fish and Wildlife, and now, the Council. Collective discussion and evaluation by these and other entities will be needed in order to make recommendations regarding the need for and prioritization of water quality modeling in the Delta.
- **Contaminants of emerging concern:** The SWRCB and RWQCBs should continue ongoing efforts to address contaminants of emerging concern. This work should include development of a work plan for conducting or requiring special studies of pollutants, including emerging contaminants and causes of toxicity in Delta waters and sediments.
- **Water quality objectives for selenium:** The identified sources of selenium as a contaminant and its potential to bioaccumulate and biomagnify in the environment are ongoing concerns. The SWRCB and San Francisco Bay and Central Valley RWQCBs should continue efforts to revise water quality objectives for selenium.

Performance Measures

Development of informative and meaningful performance measures is a challenging task that will continue after the adoption of the Delta Plan. Performance measures need to be designed to capture important trends and to address whether specific actions are producing expected results. Efforts to develop and track performance measures in complex and large-scale systems like the Delta are commonly multiyear endeavors. The recommended output and outcome performance measures listed below are provided as examples, and subject to refinement as time and resources allow. Final administrative performance measures are listed in Appendix E and will be tracked as soon as the Delta Plan is completed.

Output Performance Measures

- DWR begins constructing the North Bay Aqueduct Alternate Intake Project as soon as possible after the environmental impact report is completed. (WQ R5)
- Progress toward reducing concentrations of inorganic nutrients (ammonium, nitrate, and phosphate) in Delta waters over the next decade. (WQ R8)
- TMDLs for critical pesticides (for example, diazinon, chlorpyrifos, and pyrethroids) in the waters and sediments of the Delta are met by 2020. (WQ R8)
- A Delta regional water quality monitoring program is implemented within the first 5 years of the Delta Plan. (WQ R9)

Outcome Performance Measures

- Water quality in the Delta meets objectives established in the applicable water quality control plan. (WQ R1)
- Trends in measureable toxicity from pesticides and other pollutants in Delta waters will be downward over the next decade. (WQ R8)
- Progress toward consistently meeting applicable DO standards in the Delta by 2020. (WQ R8, WQ R11, and WQ R12)
- HABs will lessen in severity and spatial coverage in the Delta over the next decade. (WQ R3 and WQ R8)
- The spatial distribution and productivity of nuisance nonnative aquatic plants will decline over the next decade. (WQ R3 and WQ R8)

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CHAPTER 7

Reduce Risk to People, Property, and State Interests in the Delta

ABOUT THIS CHAPTER

This chapter provides an overview of flood risk in the Sacramento-San Joaquin Delta (Delta), current flood management efforts, and the most pertinent agencies and regulations. It details the Delta Stewardship Council's (Council) core strategies to reduce risk to people, property, and State interests in the Delta. These core strategies form the basis of the four policies and ten recommendations found at the end of the chapter:

- Improve emergency preparedness and response
- Finance and implement flood management activities
- Prioritize flood management investment
- Improve residential flood protection
- Protect and expand floodways, floodplains, and bypasses
- Integrate Delta levees and ecosystem function
- Limit liability

Reducing flood risks in the Delta also relies on locating urban development in the cities where levees are stronger (as proposed in Chapter 5) and retaining rural lands for agriculture, so that development in the most floodprone areas is minimized.

RELEVANT LEGISLATION

Water Code sections 85305, 85306, 85307, and 85309 require the Delta Plan to include or otherwise consider specific components to attempt to reduce risk.

> *85305(a) The Delta Plan shall attempt to reduce risks to people, property, and state interests in the Delta by promoting effective emergency preparedness, appropriate land uses, and strategic levee investments.*
>
> > *(b) The council may incorporate into the Delta Plan the emergency preparedness and response strategies for the Delta developed by the California Emergency Management Agency pursuant to Section 12994.5.*
>
> *85306 The council, in consultation with the Central Valley Flood Protection Board, shall recommend in the Delta Plan priorities for state investments in levee operation, maintenance, and improvements in the Delta, including both levees that are a part of the State Plan of Flood Control and nonproject levees.*
>
> *85307(a) The Delta Plan may identify actions to be taken outside of the Delta, if those actions are determined to significantly reduce flood risks in the Delta.*
>
> > *(b) The Delta Plan may include local plans of flood protection.*
> >
> > *(c) The council, in consultation with the Department of Transportation, may address in the Delta Plan the effects of climate change and sea level rise on the three state highways that cross the Delta.*
> >
> > *(d) The council, in consultation with the State Energy Resources Conservation and Development Commission and the Public Utilities Commission, may incorporate into the Delta Plan additional actions to address the needs of Delta energy development, energy storage, and energy transmission and distribution.*
>
> *85309 The department, in consultation with the United States Army Corps of Engineers and the Central Valley Flood Protection Board, shall consider a proposal to coordinate flood and water supply operations of the State Water Project and the federal Central Valley Project, and submit the proposal to the council for considerations for incorporation into the Delta Plan. In drafting the proposal, the department shall consider all related actions set forth in the Strategic Plan.*

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CHAPTER 7

Reduce Risk to People, Property, and State Interests in the Delta

Reducing flood risks to people, property, and State interests is critical to achieving the Delta Reform Act's coequal goals and protecting the Delta as a place. The Legislature has found that the Delta is "inherently floodprone," and that further improvements and continuing maintenance of the levee system will not resolve all flood risks (Public Resources Code section 29704). Living with risk, whether from floods, earthquakes, fires, coastal storms, or other hazards, is often part of life in California. The Delta's hazards, however, are exceptional because they affect so many State interests, including the reliability of its water supplies, the health of the Delta's ecosystem, and the qualities that make the Delta an attractive place to live, work, and recreate.

To reduce these risks to people, property, and State interests in the Delta, the Delta Reform Act requires that the Delta Plan promote effective emergency response and emergency preparedness, and promote appropriate land use (Water Code section 85305). The Delta Reform Act also directs the Council, in consultation with the Central Valley Flood Protection Board (CVFPB), to recommend priorities for State investments in levee operation, maintenance, and improvements in the Delta, including both levees that are a part of the State Plan of Flood Control and nonproject levees (Water Code section 85306).

The Council envisions a future in which risks of flooding in the Delta are reduced, despite an increase in sea levels and altered runoff patterns. The Council sees a future where Delta residents, local governments, and businesses are better prepared to respond when floods threaten. The Council envisions a future where bypasses are expanded; channels are improved; and strong, well-maintained levees protect local communities—but also protect State interests in a more reliable water supply for California, and a protected and restored Delta ecosystem. These improvements will include new or expanded floodways and bypasses, maintaining and improving levees, and floodproofing new development. The Council envisions that rural areas and the Delta's legacy communities will also be protected from flood risks by careful land use planning that discourages urban development in flood-threatened areas. The Council envisions that local agencies will be better financed and protected through a locally controlled emergency response and flood protection district, with fee assessment authority. State funds for desired projects will be focused at State interests in the Delta, but some of that activity will protect local interests as well. Eliminating flood risks will be impossible, but prudent planning, reasonable land development, and improved flood management will significantly reduce risk, and serve the coequal goals of a more reliable water supply, and a protected and restored Delta ecosystem.

Delta Hazards Threaten Both Coequal Goals and the Delta as a Place

The risks that flooding, earthquakes, and other hazards pose to the Delta imperil California's water supplies and the health of the Delta ecosystem. The channels that convey water through the Delta to users in the Bay Area, San Joaquin Valley, or Southern California, and the islands that prevent saltwater intrusion into Delta water supplies depend upon levees for their preservation. Should the levees that protect these channels fail, the impacts on water supplies could be felt statewide. Improving these Delta levees is an investment in water supply reliability. Another way to reduce these risks is for areas that use Delta water to develop plans for possible interruption of these supplies in a catastrophic event, as recommended in Chapter 3. Integrating water supply and flood control efforts is also important to optimize the management of the multipurpose reservoirs that store water for the Central Valley Project (CVP), State Water Project (SWP), and other water users. For example, a potential benefit of wide flood bypasses leading to the Delta may be greater flexibility in these reservoir operations, creating new opportunities to manage water supplies or generate hydroelectric power.

The Delta levees also affect the health of the ecosystem. Many birds, such as waterfowl or sandhill cranes, thrive in areas that depend on levees for their management. In some locations, careful removal or breaching of levees may create new habitats that benefit fish and wildlife and the ecosystem. Setting levees back deliberately, when feasible, can create both more capacity for flood flows and more habitat for fish and wildlife. But unplanned levee failures often create weed-infested depths that harbor nonnative species rather than refuges for smelt, salmon, or other preferred species. Changes in the area protected by levees also alter water circulation through the Delta, changing the benefit of flows released to protect its ecosystem.

The Delta's residents, farms, and businesses also depend on its levees. They shape the Delta landscape, protecting its farms and communities from destruction. The levee system is the foundation on which the entire Delta economy is built, the Delta Protection Commission's (DPC's) *Economic Sustainability Plan* reports (DPC 2012). Delta residents built the levee system over generations, and they are keenly interested in its maintenance and improvement. (See sidebar, Delta Disaster Recalled, for an example of the consequences of levee failure.)

DELTA DISASTER RECALLED

On a moonlit Wednesday night in June 1972, the San Joaquin River flowed slowly after one of the driest winters on record. It gnawed at the Andrus Island levee 6 miles south of Isleton between Bruno's Yacht Harbor and Spindrift Resort, opening a small hole that grew rapidly. By the time sheriff's deputies arrived on scene shortly after 1 a.m., the river had carved a 100-foot break. By 3 a.m., water covered Highway 12. Shortly after sunrise, the breach had grown to 300 feet, and volunteers were hard at work on a 1.5-mile-long bow levee to protect Isleton.

The battle to save Isleton continued throughout the day, but a rising tide and waves created by 30- to 45-mile-per-hour Delta winds hampered efforts. Within a few hours, officials ordered the evacuation of 1,400 Isleton residents and an additional 1,500 residents of Andrus and Brannan islands. At 9:45 p.m. Thursday, the bow levee breached, and a wall of water rushed into the low-lying residential area of Isleton. Although the city's business district was spared, almost all of Andrus Island and portions of Brannan Island were flooded, in some places up to 20 feet deep.

Then-Governor Ronald Reagan declared the islands a disaster area and asked President Richard Nixon to do the same. Over the next 6 months, the levee was repaired, the 12,000-acre lake that had been Brannan and Andrus Islands was drained, and life began returning to normal. A full year after the levee break, however, more than one-third of the residents had neither moved back into their homes nor begun to rebuild.

Officials estimated that damages were $21.8 million, slightly more than half of that from crop loss and saltwater damage to farmland. The cost for levee repairs was put at $800,000, and $500,000 went to pump the 20 square miles of flooded land dry. More than $1.5 million in federal disaster relief was made available. No definitive cause was ever determined for the levee breach, and a subsequent court case absolved the State of liability (DWR 1973, Sacramento River Delta Historical Society 1996).

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Flood Risk in the Delta

The Delta is an inherently floodprone area. This section provides an overview of the causes and risks of floods in the Delta. The Sacramento and San Joaquin rivers collectively drain approximately 42,500 square miles of land. Before the Delta was modified by levees and other human structures, these rivers' natural flows overflowed the Delta's low-lying islands and floodplains for long periods each spring.

The biggest floods occurred when warm Pacific storms swept in from the west and southwest, picking up moisture over the ocean and causing torrential rains when intercepted by the mountains surrounding the Central Valley. The risks of flooding were increased when large amounts of sediment were discharged to Central Valley rivers during the Gold Rush, choking their channels and raising their beds above their natural levels and surrounding lands.

Today, flooding of the Delta's complex labyrinth of islands and waterways is prevented by its levees. This system of flood control is supplemented by the flood facilities of the Sacramento River and San Joaquin River flood control projects and multipurpose reservoirs such as Shasta, Folsom, and Millerton lakes and Lake Oroville on the Sacramento and San Joaquin rivers and their tributaries, which hold back floodwater and provide water supplies and other benefits described in Chapter 3.

Many Delta levees were initially constructed more than a century ago using primitive materials and equipment. History has shown that structural failures of the levee system occur as a result of extraordinary events, imperfect knowledge, and imperfect materials. Delta levees face potential threats such as large runoff events, extreme high tides, wind-generated waves, earthquakes, subsidence, and sea level rise. Individually, each of these threats is enough to cause serious concern; together, they represent the potential for catastrophic disruption of the Delta and its economic and ecological services.

A mass or even partial failure of the levee system would have real life-and-death impacts and property losses that could total billions of dollars. Delta flooding could interrupt the conveyance of water through the Delta for the SWP, the CVP, in-Delta users, the Contra Costa Water District, the cities of Antioch and Stockton, and others who depend on the Delta for reliable water supplies (see Chapter 3 for a discussion of water supply reliability). Levee failures could also damage key features of the Delta ecosystem, including managed wetlands in Suisun Marsh and habitats of wintering greater sandhill cranes at Staten Island and nearby tracts. Unplanned levee failure could also degrade water quality in the Delta, because tidewaters would flood into the bowl created by subsidence of Delta islands. These failures would draw saltwater from San Francisco Bay and pollute Delta water with flood debris, farm chemicals, and other pollutants.

Levee failures also could flood homes, farms, and businesses, including historic structures in the legacy communities, and interrupt recreation and tourism. As noted in Chapter 5, about 116,000 residential structures are located in the 100-year floodplain of the Delta, mostly near Sacramento, West Sacramento, and Stockton. Also, 8,000 residences are below mean higher high water (DWR 2008b). Serious consequences also could result from flood-related damage to critical infrastructure in the Delta, including radio, cellular telephone, and television transmission towers; electrical transmission lines, including Pacific Gas and Electric Company, Sacramento Municipal Utility District, and Western Area Power Administration lines; natural gas pipelines serving local gas fields and regional transmission systems; petroleum pipelines; three state highways; and three interstate highways (DWR 2011a).

In simplistic terms, the concept of flood risk can be described as the likelihood of a flood event occurring and the consequences of that event. To many, flood risk simply means the chance a storm event will overwhelm the flood control system to some extent. Figure 7-1 illustrates the variables, namely the probability of flooding and the financial consequences. However, there are many other causes of flood risk, and the consequences can be far more complicated than the immediate damage to property.

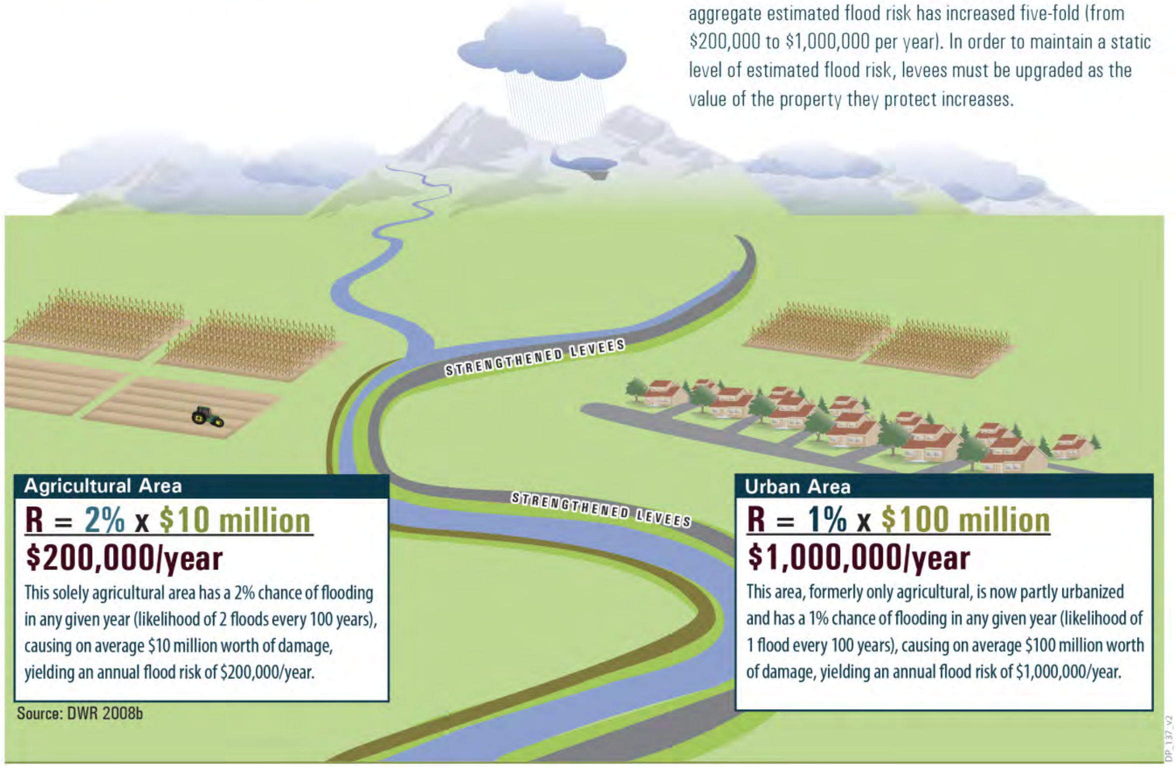
Understanding Delta Flood Risk

Flood risk reflects both the probability of flooding and the consequences that would result from flooding. Flood risk can be calculated as:

R = % x $

Annual Flood Risk = Probability of Flooding X Financial Consequence

The scenario to the right of the river depicts how increasing the value of property, primarily through urbanization, will increase the flood risk in the area. Even though the levees in the urbanizing area have been upgraded to reduce the annual probability of flooding to 1% (or 1 flood every 100 years), by increasing the value of property behind these levees, the aggregate estimated flood risk has increased five-fold (from $200,000 to $1,000,000 per year). In order to maintain a static level of estimated flood risk, levees must be upgraded as the value of the property they protect increases.



Agricultural Area

R = 2% x $10 million

$200,000/year

This solely agricultural area has a 2% chance of flooding in any given year (likelihood of 2 floods every 100 years), causing on average $10 million worth of damage, yielding an annual flood risk of $200,000/year.

Urban Area

R = 1% x $100 million

$1,000,000/year

This area, formerly only agricultural, is now partly urbanized and has a 1% chance of flooding in any given year (likelihood of 1 flood every 100 years), causing on average $100 million worth of damage, yielding an annual flood risk of $1,000,000/year.

Source: DWR 2008b

Figure 7-1

The best defense against these risks is first to better understand the Delta's flood hazards, and then manage and control those risks to the extent possible through public awareness; adequate emergency management planning; structural and nonstructural improvements, including enforcement of existing flood management regulations; and repairs, rehabilitation, and improvement of levees (including setback levees) and flood channels. Improving our understanding of risks through further evaluation and analysis of the flood control system and the assets it protects is essential to developing a rational, prioritized approach to flood management and public investment.

Floods

Flooding during winter storms that results in high water surface elevations and high winds has been a common cause of levee failures in the Delta. For example, the Sacramento River at Rio Vista may flow in excess of 300,000 cubic feet per second (cfs) during winter and early spring floods, 30 times typical late-summer flows of 10,000 cfs. Peak discharges place high stress on Delta levees and can create flood conditions, especially when coupled with high tides.

The likelihood of levee failures caused by high water is substantial, based on the historical performance of these levees over the last century. During the last century, there have been more than 140 levee failures and island inundations, most of which occurred during flood seasons (DWR 2005). High water in the Delta can overtop levees, as well as increase the hydrostatic pressure on levees and their foundations, causing instability and increasing the risk of failure due to through-levee and/or under-levee seepage. Most levee failures in the Delta have occurred during winter storms and related high-water conditions, often in conjunction with high tides and strong winds.

Earthquakes

The Delta's levees are also at risk from the active seismic zones west of the Delta, including the San Andreas and Hayward faults. Less active faults underlie the Delta. A strong earthquake could damage Delta levees because of the potential for liquefaction of levee embankments and foundations. Saturated levees composed of dredged materials in other parts of the country and the world have performed poorly during moderate to strong earthquake shaking (DWR 2009; Delta Stewardship Council Staff 2010a). If a levee failed during high flows or if a flood were to occur soon after an earthquake, the protected area could be inundated.

The risks of earthquakes causing levee breaches and island inundations in the Delta have long been recognized. A California Department of Water Resources (DWR) report begins:

> *There is a long history of levee failures in the Delta that have resulted in extensive economic damage, but no failures of Delta levees are known to be directly attributable to earthquakes. Even so, two factors indicate a possible bleak picture for the future of many Delta levees. First, no serious causative quakes have occurred on the nearby major faults since the San Francisco earthquake of 1906. Second, the Delta levees of today are vastly different than those in the 1906 Delta, which had limited size and extent. (DWR 1980)*

The DWR Delta Risk Management Strategy Phase 1 study evaluated the performance of Delta levees under various seismic threat scenarios, and analyzed potential consequences for water supply, water quality, ecosystem values, and public health and safety. The study concluded that a major earthquake of magnitude 6.7 or greater in the vicinity of the Delta Region has a 62 percent probability of occurring sometime between 2003 and 2032 (DWR 2009). Figure 7-2 illustrates a potential flood scenario in which a 6.5-magnitude earthquake causes a 20-island failure. Although the probabilistic nature of earthquake prediction makes it difficult to quantify the timing and magnitude of seismic threats, it is important to address the threats posed by earthquakes to the Delta levee system because of the potential adverse effects of such events.

High Tides and Sunny-day Risks

Even without an earthquake or flood, Delta levees can fail during high tides or even on sunny days. Generally, these failures may be the result of a combination of high tide, and pre-existing internal levee and foundation weaknesses caused by burrowing animals, internal erosion of the levee and foundation through time, and human interventions such as dredging or excavation at the toe of the levee (DWR 2008b). Examples of sunny-day failures include the Brannon Andrus Tract in 1972 and Upper Jones Tract in 2004. It is estimated that, based on current conditions, a sunny-day failure would occur once every 9 years on average (DWR and DFG 2008).

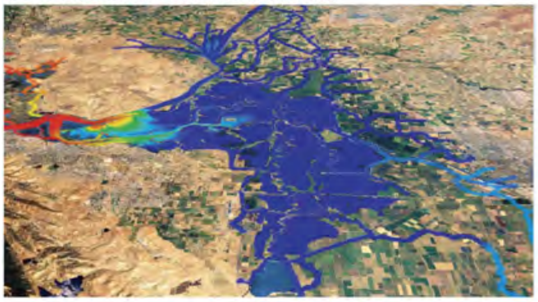
Other hazards that affect the performance of Delta levees include encroachments, penetrations, and burrowing animals. Encroachments such as structures or farming practices on or close to the levee; penetrations of the levee, such as culverts or pipelines; and burrows created by rodents, especially beavers, muskrats, and squirrels, can weaken the structural integrity of levees. Because of unregulated historical construction, levees also contain many hidden hazards. Active programs of inspection, oversight, and maintenance are essential to minimize these hazards.

Simulation of Delta Salinity after a 20-island Failure Caused by a Magnitude 6.5 Earthquake

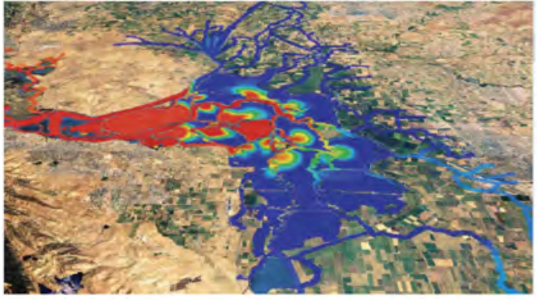
Electrical Conductivity (μmhos/cm)

400 5000

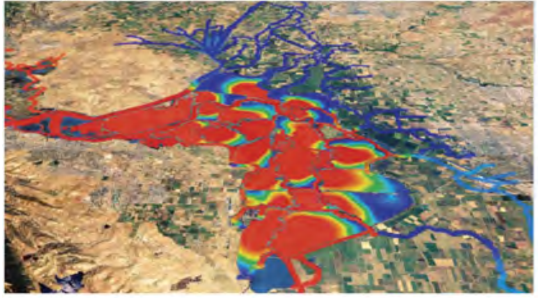
0–6 hours: Islands flood with fresh water



12–24 hours: Salt water intruding into Delta



1–7 days: Salt water throughout Delta



30 days: A saline estuary

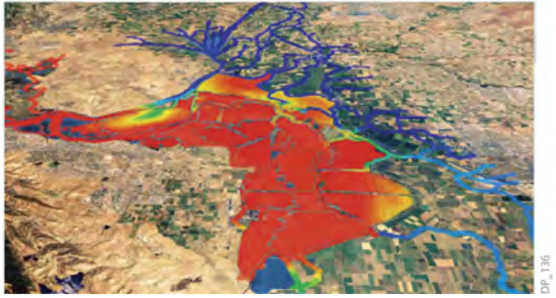


Figure 7-2 *Source: MWD 2010*

Land Subsidence

Because of the land subsidence described in Chapter 5, much of the central Delta is below sea level. Some islands are 12 to 15 feet below sea level, requiring levees 20 to 25 feet in height that act as dikes, holding back water continually rather than only during seasonal floods or extreme tides. As subsidence progresses, accommodation space increases, and levees must be continually maintained, strengthened, and periodically raised to support the increasing hydraulic stresses (Miller 2008, Mount and Twiss 2005). The hydraulic stress also can drive seepage through and under levees, and place levee foundations under more stress. The thinning of the peat soil layer also causes shallow or artesian groundwater conditions. More seepage onto islands will increase the drainage costs associated with additional pumping and decrease levee stability (Deverel and Leighton 2010).

Climate Change and Flood Risk

Climate change has major implications for the Delta, and especially for flood risk management. It is estimated that by the year 2100, sea levels may rise 31 to 69 inches (California Climate Action Team 2010, California Ocean Protection Council 2011), putting additional stress on levees and increasing their risk of failure. Projected changes in the timing and intensity of runoff may increase peak storm runoff and high-frequency flood events (DWR 2008c). Such floods could interrupt water conveyance through the Delta for those who depend on the Delta for water.

Additionally, scientific understanding of large-scale precipitation events is growing, as demonstrated by the ARkStorm scenarios being investigated by the U.S. Geological Survey, which indicate that massive storms and subsequent flooding have occurred and are likely to occur again (USGS 2011). Failure of significant parts of the Delta's flood management system may be unavoidable.

Planning for Flood Management

This section summarizes the current state of flood management planning for the Delta. To reduce the risk of flooding, Delta landowners, local governments, and State and federal agencies have planned and built an extensive levee system in the Delta, and significant flood control works upstream of the Delta. Other government flood control programs plan for emergency response in the event of floods, or help manage flood risks through land use planning, building standards, and flood insurance. The Delta Reform Act refers to these government-sponsored flood control programs in its provisions regarding covered actions (Water Code section 85057.5(a)(4)). The sidebar, What Is a Government-sponsored Flood Control Program?, highlights those programs referenced in statute; and proposed actions in the Delta that will have a significant impact on the implementation of one of these programs may be considered covered actions. Chapter 2 provides details about covered actions.

There are more than 1,000 miles of project and nonproject levees in the Delta and Suisun Marsh. Differences in how levees are classified can influence reports about their length and condition. Approximately 65 percent of the levees in the Delta and all levees in the Suisun Marsh are owned or maintained by local agencies or private owners and are not part of the flood control projects on the Sacramento or San Joaquin rivers. Most of these nonproject levees are maintained by local reclamation districts created and funded by landowners, initially for the purpose of draining ("reclaiming") Delta islands and tracts. The reclamation districts continue to maintain levees and other water control facilities today. These nonproject levees are defined in Water Code section 12980(e).

Many facilities throughout the Delta also drain rainfall runoff from land into Delta channels. Local cities and districts own and maintain urban storm drains in developed areas. Stockton, Sacramento, West Sacramento, Lathrop, Manteca, and Tracy are Delta cities with storm drainage facilities.

WHAT IS A GOVERNMENT-SPONSORED FLOOD CONTROL PROGRAM?

Any State or federal strategy, project, approval, funding, or other effort that is intended to reduce the likelihood and/or consequence of flooding of real property and/or improvements, including risks to people, property, and State interests in the Delta, that is carried out pursuant to applicable law, including, but not limited to, the following code:

- State Water Resources Law of 1945, Water Code section 12570 et seq.
- Sacramento-San Joaquin River Flood Control Projects (Flood Control Act of 1941, Public Law 77–228)
- Local Plans of Flood Protection (Water Code section 8201)
- Central Valley Flood Protection Plan (Water Code section 9600 et seq.)
- Subventions Program, Special Projects Program (Water Code section 12300 et seq.)
- Way Bill 1973 – Subventions Program, Special Projects Program (Water Code section 12980 et seq.)
- Central Valley Flood Protection Board Authority (California Code of Regulations, Title 23, Division 1)
- National Flood Insurance Program (National Flood Insurance Act of 1968, 42 United States Code 4001 et seq., Public Law 90-448)

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Most Delta islands have a network of agricultural drains and pumps to pump runoff into the Delta channels. Some Delta channels have been dredged to increase their capacity to carry floodwater and to obtain material for levee construction and maintenance.

The flood control projects on the Sacramento and San Joaquin rivers include approximately one-third of the Delta's levees. Known as "project levees," they begin on the left bank of the Sacramento River at Sherman Island, and line most of the riverbanks, as well as the Sacramento River Deep Water Ship Channel and some connecting waterways, north to Sacramento and beyond. The Delta Cross Channel's control gates are an important feature of this levee system, closing during high flows to keep the Sacramento River's floodwaters out of the central Delta. The flood control project also includes the Yolo Bypass, the broad, managed floodplain in Yolo County west of West Sacramento. The wide bypass, which is confined by project levees, draws floodwater through weirs above Sacramento to lower flood heights on the Sacramento River and its tributaries, discharging back to the Delta above Rio Vista. The Yolo Bypass floods about once every 3 years, between December and February. On the San Joaquin River, project levees line the riverbanks from Old River to Stockton. Figure 7-3 shows the locations of project and nonproject levees in the Delta.

Recent evaluations show that some of the flood control project facilities on the Sacramento and San Joaquin rivers are not adequate. Because the system was intended partly to flush Gold Rush-era sediment from rivers and channels, the project levees were often built close to the riverbanks, and are prone to erosion. Many of the system's channels have inadequate capacity to carry the flows for which they were designed, and many levees do not meet contemporary design standards (DWR 2011c).

The CVFPB, as part of its responsibility to oversee the flood control projects on the Sacramento and San Joaquin rivers, has adopted regulations to control encroachments on the project and some of the streams that flow into it. It also regulates encroachments within designated floodways, which are the channels of a river or other watercourse and the adjacent land areas that convey floodwaters (California Code of Regulations [CCR], Title 23, Division 1, Chapter 1, Article 2, Section 4). In the Delta, designated floodways include the Cosumnes River's floodplain and the confluence of the San Joaquin River and the Stanislaus River upstream from Paradise Cut.

Some levees are neither project levees nor nonproject levees. These "unattributed levees" include hundreds of miles of levees in Suisun Marsh and the Delta, and are not part of any State-financed flood control program. They also include some that are unmaintained along the perimeter of permanently flooded islands and no longer serve flood control or drainage purposes.

Multipurpose reservoirs in the Sacramento and San Joaquin river watersheds that play a role in California's water supply also serve critically important roles in managing floods that affect the Delta. The CVP's Shasta, Folsom, and Millerton lakes and New Melones Reservoir; the SWP's Lake Oroville; and other reservoirs are operated in accordance with flood control rules established by U.S. Army Corps of Engineers (USACE), reserving space to capture flood flows that can be released downstream gradually so that channels are not overwhelmed.

Many studies and planning efforts addressing flood management and emergency preparedness, response, and mitigation are under way, and will be considered by the Council for ongoing Delta flood risk management. These studies, efforts, and programs include the following:

- ***Central Valley Flood Protection Plan* (CVFPP).** This strategic plan for improving the flood control projects on the Sacramento and San Joaquin rivers recommends approaches for reducing flood risk and improving the flood control project, including expansion of the Yolo Bypass and construction of a new San Joaquin River Bypass at Paradise Cut (DWR 2011c) (see sidebar, Central Valley Flood Protection Plan).
- **DWR's FloodSAFE Initiative.** In 2006, DWR launched FloodSAFE California—a multifaceted initiative to improve public safety through integrated flood management.
- **DWR's Delta Levees Program.** This program encompasses both the Delta Levees Maintenance Subventions and Delta Levees Special Flood Control Projects programs, which provide State cost-share funding for Delta levee maintenance and upgrades.
- ***Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force Report.*** This report responds to Senate Bill (SB) 27 (Water Code section 12994.5), which called for the task force to make recommendations to the Governor about Delta multi-hazard emergency response and recovery issues.

- **USACE Delta Islands and Levees Feasibility Study, Long-Term Management Strategy for Dredging and Dredge Material Placement, Periodic Inspection Program, and Levee Safety Portfolio Risk Management System.** USACE has multiple programs addressing Delta-related flood management issues, including levee safety, levee integrity, and the beneficial reuse of dredged material.
- **CVP and SWP Reoperation Studies.** DWR's Forecast-coordinated Operations Program and Systems Reoperation Program address reservoir operational criteria, as noted in Chapter 3.

The Council will consider the findings of these studies and may incorporate them into future Delta Plan updates. The CVFPP and FloodSAFE include many concepts relevant to flood protection in the Delta. At the federal level, the National Committee on Levee Safety (2009) submitted a report to Congress that outlined the critical components of a National Levee Safety Program, and a high-level timeframe and steps for its creation. It is up to Congress to act on these recommendations, which will be monitored by the Council as they relate to the Delta Plan.

The CVFPB, DWR, and USACE each play unique and critical roles in Delta flood risk management. Because of this, the Council's role in facilitation, coordination, and integration of various agencies and other parties is of particular importance. Frequent, ongoing collaboration with other State, federal, and local agencies to improve communication and coordination is essential to meeting the Delta Plan's flood management objectives.

The Delta's Levees

The levees within the legal Delta protect approximately 740,000 acres of land. They define the Delta's physical characteristics; influence the reliability of its water supplies and its ecosystem health; and are critical to the Delta's residents, farms, businesses, cities, and legacy communities. Because many Delta levees protect land below sea level, they hold back water all day, year-round, rather than only during floods, and so are called "the hardest working levees" in America.

CENTRAL VALLEY FLOOD PROTECTION PLAN

The Central Valley Flood Protection Act of 2008 directed DWR to prepare the CVFPP. The CVFPP is a flood management planning effort that addresses flood risks and ecosystem restoration opportunities in an integrated manner. It specifically proposes a systemwide approach to flood management for the areas currently protected by facilities of the State Plan of Flood Control (SPFC). The CVFPP was adopted by the CVFPB in June 2012. It is expected that the CVFPP will be updated every 5 years thereafter.

The CVFPP proposes a systemwide approach to address the following issues:

- Physical improvements in the Sacramento and San Joaquin river basins
- Urban flood protection
- Small community flood protection
- Rural/Agricultural area flood protection
- System improvements
- Non-SPFC levees
- Ecosystem restoration opportunities
- Climate change considerations

The geographic scope of the CVFPP includes the portions of the Delta covered by the SPFC, including about 65 miles of urban, nonproject levees at Stockton; approximately two-thirds of Delta levees are not addressed in the CVFPP.

The effects of systemwide improvements directed by the CVFPP and the potential of redirected impacts to areas within the Delta will be monitored by the Council to ensure alignment with the coequal goals and the Delta Reform Act. Additionally, the Council may, at its discretion, incorporate those portions of the CVFPP into the Delta Plan to the extent that those portions promote the coequal goals (Water Code section 85350).

The 2012 CVFPP is only a descriptive document, highlighting a planning perspective at a reconnaissance level. Follow-on feasibility studies and project-specific development activities will be conducted over the next several years. The Council will continue to monitor and provide input to those activities to ensure that Delta flood risk issues are considered. Flood system improvement actions undertaken upstream of the Delta are of particular concern if not coupled with in-Delta actions that reduce overall systemwide flood risk.

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Levees in the Delta

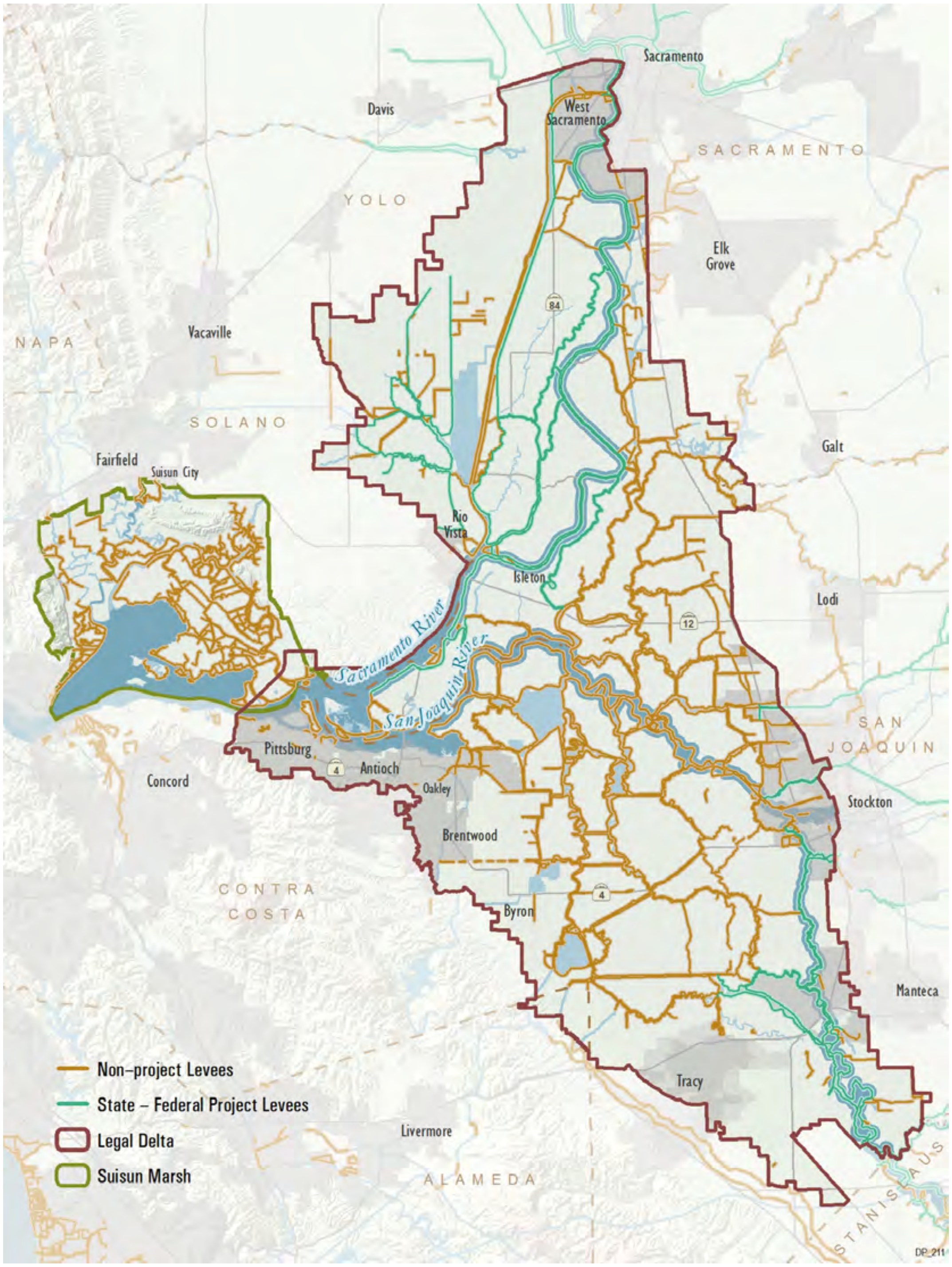


Figure 7-3 *Source: DWR 2011e*

Existing Levee Standards and Guidance

It is more important than ever that the Delta's levees are designed, constructed, and maintained to provide a level of flood risk reduction commensurate with the coequal goals and protection of the Delta's unique values as a place. Over the last few decades, State and federal agencies have developed guidelines and standards for levees. These standards establish minimum criteria for levee design and maintenance. The standards include (1) the level of flood protection California has prescribed for the Central Valley's urban areas, (2) whether sufficient protection is provided by the levees to exempt development financed with federally backed mortgages from requirements to obtain flood insurance, and (3) whether property and infrastructure protected by the levees (including the levees themselves) are eligible for assistance in the event of a catastrophic emergency, including aid from USACE to rehabilitate levees damaged in an emergency or for disaster assistance from the Federal Emergency Management Agency (FEMA).

Four levee standards and guidance applicable to the Delta are discussed below (and shown on Figure 7-4); they are ordered from highest to lowest level of flood protection:

- **DWR 200-year Urban Levee Protection (DWR - 200 Year):** This standard goes beyond criteria for levee height and geometric design to include requirements for freeboard, slope stability, seepage/underseepage, erosion, settlement, and seismic stability (DWR 2011b). It protects against a flood that has a 0.5 percent chance of being equaled or exceeded in any given year (a 200-year level of flood protection). This urban levee standard is the only levee standard that specifically links land uses to levee criteria. State law requires that by 2025, floodprone urban areas with over 10,000 residents must meet this 200-year flood protection standard (Government Code section 65865.5(a)(3)). Compliance likely will be achieved by upgrading levees to meet the 200-year design standard, under development by DWR. Sacramento, West Sacramento, and Stockton are planning levee improvements to attain this level of protection.

  Very few levees in the Delta meet this standard because most Delta levees do not protect urban areas. Under existing law, rural levees are not required to meet this standard.

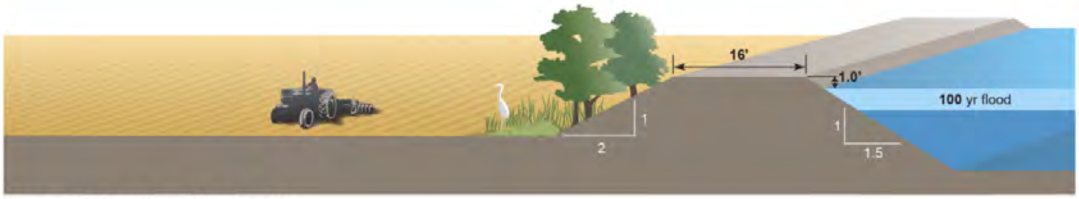
- **FEMA 100-year (Base Flood) Protection (FEMA – 100 Year):** This "insurance" standard, often called the "1 percent annual chance flood" level of protection, provides criteria that levees must meet to protect against the flooding that is the basis for FEMA's flood insurance rate maps (44 Code of Federal Regulations 65.10). It is often used with established USACE criteria to prescribe requirements for levee freeboard, slope stability, seepage/underseepage, erosion, and settlement. The standard generally does not address seismic stability. In communities where levees provide this level of flood protection, new developments are not required to meet federal floodproofing standards and can obtain federally guaranteed mortgages without purchasing flood insurance.

  Few Delta levees outside of cities meet this standard, and many urban levees need improvement to meet it.

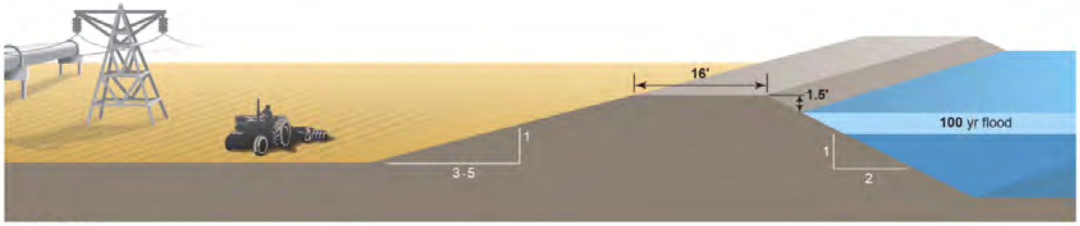
- **Public Law 84-99 (PL 84-99):** The PL 84-99 standard is a minimum requirement established by USACE for levees that participate in its Rehabilitation and Inspection Program (33 United States Code 701n) (69 Stat. 186). Twenty-five Delta reclamation districts, protecting about 31 percent of the legal Delta's land behind about 516 miles of levees, are at or above this standard, according to a recent report to the Council by DWR (DWR 2012). Delta islands or tracts that meet this standard are eligible for USACE funding for levee rehabilitation, island restoration after flooding, and emergency assistance, provided that the reclamation district is accepted into the USACE's program and passes a rigorous initial inspection and periodic follow-up inspections. Eligibility for PL 84-99 was formerly based primarily on levee geometry with minimum freeboard and maximum steepness of slopes. USACE's periodic

Levee Guidance

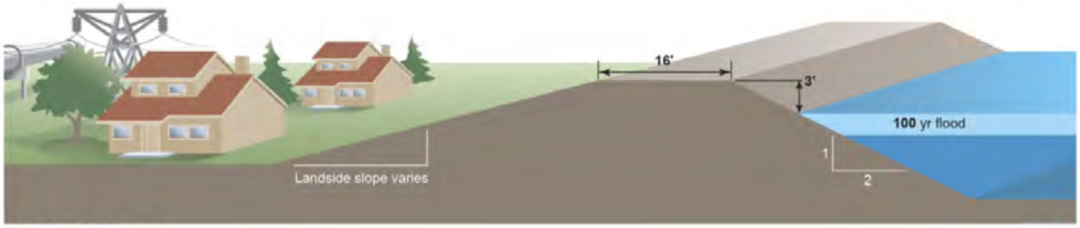
Wetlands/Habitat



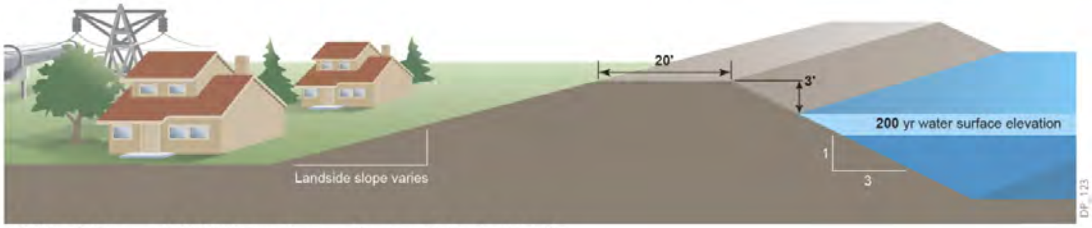
Hazard Mitigation Plan (HMP)



PL 84-99



FEMA - 100 year



DWR - 200 year (DWR Urban Levee Design Criteria 2011)

Figure 7-4

Source: Adapted from Delta Vision Blue Ribbon Task Force 2008 and DWR 2011b inspection program incorporates other elements into eligibility, including presence of structure encroachments, vegetation, rodent control programs, and more. The standard for levee geometry implies a minimum levee height and a slope stability factor of safety, but is not associated with a level of protection (such as a 100-year flood) and does not address seismic stability. In 1987, USACE developed a Delta-specific standard based on the Delta's particular organic soils and levee foundation conditions. The CALFED Record of Decision set a goal of improving Delta levees to the PL 84-99 standard, as does the DPC Economic Sustainability Plan, but funding has been inadequate to attain this objective.

- **FEMA Hazard Mitigation Plan (HMP) Guidance:** FEMA, DWR, the California Office of Emergency Services (now the California Emergency Management Agency [Cal EMA]), and the Delta levee-maintaining agencies negotiated the HMP guidance to reduce the likelihood of repetitive flood damage to Delta levees and islands, so that FEMA disaster assistance would not be requested repetitively for the same islands after minor floods. Fifty-three of the Delta's reclamation districts, protecting over 47 percent of the legal Delta's acreage, fall below this standard, which 139 miles of Delta levees do not meet (DWR 2012). Local communities that do not meet the HMP guidance are not eligible for FEMA disaster reimbursement for flood fights or assistance if levees fail or islands flood. If even a portion of the levee around an island or tract does not meet the HMP guidance, assistance from FEMA to recover from levee damage is unavailable. Fifteen districts comply with this guidance, but are below the PL 84-99 standard. FEMA and Cal EMA have a memorandum of understanding, updated in 2010, that sets forth the requirements for FEMA public assistance funding for emergency flood fighting, emergency repair, permanent restoration, and/or replacement of eligible damaged nonproject levees within Delta reclamation districts (Cal EMA and FEMA 2010). The guidance is based on geometric criteria for the levees. The HMP guidance, negotiated between 1983 and 1987, was intended as an interim guidance, but has not been adjusted using subsequent or projected flood elevations.

No State standards currently address design criteria for flood protection of the state highways and interstate highways that traverse the Delta. Federal standards require that interstate highways must be protected from 50-year flood events to qualify for Federal Highway Administration funds (23 Code of Federal Regulations 650.115). Because most roads in the Delta were constructed before these standards were developed, they do not meet the standards. For example, sections of State Route 12 are 10 feet or more below sea level. A flood on the islands this highway traverses could interrupt transportation and trade, and put motorists at risk.

Levees and Ecosystem Function

Historically, most discussion of levees has emphasized reducing flood risks to life and property. However, habitat and ecosystem values and functions can provide multiple benefits, and must be considered in flood management planning and actions. For example, the CVFPP includes a conservation framework and strategy that outline how environmental elements can be integrated into flood management activities and provide an environmental guide for flood project planning. Setting levees back from the riverbank can expand flood conveyance capacity and reduce flood risk while providing ecosystem restoration and recreational opportunities (USACE 2002). Setback levees also allow opportunities for construction of an improved levee foundation and section using modern design and construction practices, thereby reducing risk of failure.

Much discussion has occurred on how to more effectively accommodate ecosystem function with the current levee system, highlighting the following issues (Healey and Mount 2007):

- Current levees tend to be narrow, with steep waterside slopes that provide little upland habitat value.

- Setback levees may provide habitat value and increased levee integrity.
- Levees can be used to promote specific habitat types (such as waterfowl habitat) by ensuring that some areas of freshwater marsh are sustained.
- Where lands are not heavily subsided, levees can allow for multiple land uses including habitat management and wildlife-friendly agriculture.
- Allowing levees to fail on deeply subsided islands would not generate any obvious ecological benefits.
- Subsidence reversal on deeply subsided islands would rely on levees to appropriately manage water levels during tule growth.

As management efforts in the Delta proceed, it will be important to consider ecosystem functions and their interactions with the levee system, as discussed in Chapter 4. An example where these interactions are already being debated is the USACE's current policy requiring removal of vegetation from levees. Scientific support for and against this policy is mixed. Concerns with maintaining woody vegetation on levees include difficulties with inspection and flood fighting, potential for root holes, and trees toppling from erosion. Other evidence, however, suggests that woody shrubs and small trees on levees enhance levee structural integrity while providing environmental benefits. A study on a channel levee along the Sacramento River concluded that roots reinforced the levee soil and increased shear resistance by providing increased stability against slope failures (Shields and Gray 1992). In either case, the widespread removal of vegetation from Delta levees could have significant adverse environmental impacts that are not well understood.

Floodplains and Channels

Floodplains and channels that provide the capacity to carry and store flood flows are critical for managing flood risks, and for overall Delta water management and ecosystem integrity. The CVFPB and FEMA both play roles in designating floodways and floodplains to accommodate flood flows.

The CVFPB regulates encroachment in floodplains by designating floodways in the Sacramento River and San Joaquin River drainages, including the Delta (Water Code section 8609). A "designated floodway" is the channel of the stream and that portion of the adjoining floodplain, as shown on Figure 7-5, reasonably required to provide for the passage of a specified flood. It may also be the floodway between existing levees as determined by the CVFPB.

The CVFPB regulates encroachments within designated floodways and regulated streams through its permitting authority. The encroachment permit process applies to all projects, existing and proposed (including habitat restoration projects), within State/federal flood control project levees, designated floodways, bypasses, and regulated streams (CCR, Title 23, Division 1). The CVFPB should be consulted prior to the consideration of any projects that may be in a designated floodway in the Delta. Appendix L includes a map of the CVFPB's jurisdictional areas in the Delta.

Additionally, under the National Flood Insurance Program, FEMA maps floodplains that have a 1 percent chance of flooding in any year (a 100-year flood). FEMA works with participating communities to regulate development within these floodplains according to federal regulations. No new construction, substantial improvements, or other development (including fill) may be permitted within specified flood zones on the community's Flood Insurance Rate Map unless it is demonstrated that the cumulative effect of the proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than 1 foot at any point within the community.

In some flood channels and bypasses, dredging may have benefits because it increases channel capacity and also provides material that can be used for levee maintenance and other flood risk management activities. Because some

Conceptual Diagrams of Floodways

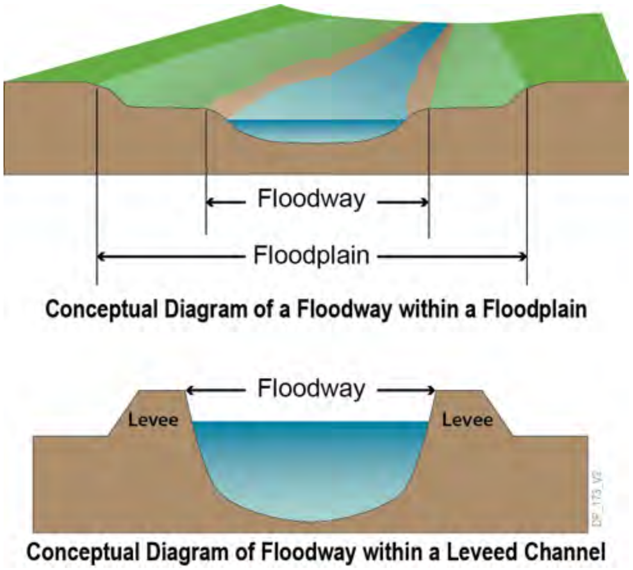


Figure 7-5 The floodway is the channel of the stream and that portion of the adjoining floodplain reasonably required to provide for the passage of a specified flood; it is also the floodway between existing levees as determined by the CVFPB or the Legislature.

Source: FEMA 2006

portions of the Delta are within a tidal pool and other areas are riverine, the efficacy of dredging must be addressed on a site-specific basis and cannot simply be considered useful on a Delta-wide basis.

The benefits and impacts of dredging Delta channels are being investigated by a consortium of federal and State agencies, including U.S. Environmental Protection Agency, USACE, DWR, and the Regional Water Quality Control Boards, under the Delta Dredged Sediment Long-Term Management Strategy (LTMS) Program. The LTMS is designed to improve operational efficiency and coordination of the collective and individual agency decision-making responsibilities resulting in approved dredging and dredged material management actions in the Delta. Approved dredging and dredged material management actions will take place in a manner that protects and enhances Delta water quality, identifies appropriate opportunities for the beneficial reuse of Delta sediments for levee rehabilitation and ecosystem restoration, and establishes safe disposal for materials that cannot be reused (USACE 2007).

Investment in Reducing Risk

Because the Delta's levees protect residents; agricultural land; water supplies; and energy, communications, and transportation facilities, the State has invested considerable funding in Delta levees over several decades through various legislative actions. Legislation sponsored by Senator Howard Way in 1973 established the Delta Levees Maintenance Subventions Program, SB 34 (1988) established the Delta Levees Special Flood Control Projects Program, and Assembly Bill 360 (1996) extended these two programs and initiated a requirement for net habitat enhancement. Bond measures passed since the late 1990s have provided sizeable but one-time funding for levee maintenance, repair, and improvements. Propositions 84 and 1E provided substantial public financing toward most of the recent Delta levee projects. An estimated $700 million of State taxpayer money has been spent by DWR on Delta levee maintenance and improvements since the Delta levee funding programs began in the 1970s. This includes $274 million of bond funds that are encumbered for future Delta levee projects. Funding to improve levees that protect urban and urbanizing areas within the Delta is currently provided by the State via the Early Implementation Program managed by DWR.

The Delta's project levees are authorized as part of the federal flood control project and so are eligible for federal funding (as well as the maintenance subventions mentioned below). The CVFPB serves as the nonfederal partner to USACE for the Delta's project levees.

State investments for nonproject levees in the legal Delta are distributed according to guidelines and criteria of the Delta Levees Maintenance Subventions Program or Delta Levees Special Flood Control Projects Program. These two programs provide State matching funds for maintaining and improving Delta levees. Local agencies in the legal Delta receive partial reimbursement for levee maintenance and rehabilitation from the State when funding is available. Currently, the State contributes up to 75 percent of qualifying costs for maintenance of many Delta levees. Local levee-maintaining agencies provide local cost-share matches, and both local and State efforts contribute to Delta flood risk reduction by maintaining continuous efforts to preserve Delta levees. It is often difficult for local agencies to raise funds for the local cost share of State and federal assistance programs. Funding assistance provided by the Delta Levees Maintenance Subventions Program is governed by guidelines developed by DWR and adopted by the CVFPB. State funds are not available for levee maintenance or improvement in most of Suisun Marsh.

Although the State has contributed the majority of costs for maintaining and improving Delta nonproject levees for many years, the concept of shared responsibility with local landowners is key to the long-term success of the Delta levee system. Neither the State nor the federal government is legally obligated to pay the full cost of Delta flood protection projects. The continued participation and financial support of local reclamation districts is essential. As noted in the Delta Reform Act's Section 85003(b), "Delta property ownership developed pursuant to the federal Swamp Land Act of 1850, and state legislation enacted in 1861, and as a result of the construction of levees to keep previously seasonal wetlands dry throughout the year. That property ownership, and the exercise of associated rights, continue to depend on the landowners' maintenance of those nonproject levees and do not include any right to state funding of levee maintenance or repair."

Prioritizing State Investment in Levees

The Delta Reform Act requires that State investments in Delta levees be prioritized to reduce risks to people, property, and State interests in the Delta (Water Code sections 85305(a) and 85306). Prioritizing investment is necessary to ensure that limited public funds are expended responsibly for improvements critical to State interests, rather than simply applying one objective to all Delta levees regardless of priority. These priorities, in combination with the Delta Reform Act directive that State agencies act consistently with the Delta Plan, will ensure that State spending on Delta levees reflects these priorities in the future. The Delta Reform Act provides that activities of the Council in determining priorities for State levee investments in Delta levees do not increase the State's liability for flood protection in the Delta or its watershed (Water Code section 85032(j)).

This Delta Plan outlines a process to prioritize State investments in levee operation, maintenance, and improvements in the Delta. It is also important to prioritize interim actions while longer-term guidelines are being established. Interim actions taken should consider and, where feasible, incorporate habitat and ecosystem values and enhancement in their development and implementation. This will allow for a more coordinated, effective approach to reducing Delta flood risk and prioritizing both immediate and long-term State investments. This approach will also take into account future actions that may be proposed through other planning efforts such as the CVFPP and Bay Delta Conservation Plan.

To effectively prioritize State investments in levees, a framework is needed to adequately assess Delta flood risk. This framework should include the following steps:

- Assess existing Delta levee conditions. Initially, a sufficient understanding of the current status of Delta levees is needed to establish baseline conditions against which future risk reduction efforts can be gauged. Because Delta levee conditions change, it is critical to conduct periodic assessments so that maintenance and improvement actions can be directed rationally. Assessment methods should be used that provide sufficient information to portray a reasonable snapshot of conditions.
- Develop an economics-based risk analysis for each Delta tract and island. This analysis must address several critical parameters, including life safety, private property, impacts on State water supply, critical infrastructure,

Delta water quality, ecosystem values, and systemwide integrity. Accepted risk analysis methods should be used, such as those developed by USACE (1996, 2006). This analysis could include "expected annual damage" assessments as a metric for analyzing flood risk. This approach, which integrates the likelihood and consequences of flooding, provides values that are useful for comparing flood risk at various locations and for ranking alternative levee projects.

- Conduct ongoing Delta flood risk analyses in an open manner for the public. Baseline and subsequent analytical efforts should always be conducted in manner open to scrutiny, with results being readily available for decision makers, interested parties, and the general public. Flood risk analyses will need to take into account future actions that may be proposed through other planning efforts such as the CVFPP and Bay Delta Conservation Plan.
- Develop an updated understanding of Delta hydrology. An updated understanding of water surface elevations in the Delta is critical for levee design purposes and should be addressed.

The approach must be based on sound scientific and engineering principles, and incorporate appropriate economic and hydrologic data.

As these long-term priorities for State investments in levee operation, maintenance, and improvements are developed, State funds for Delta levee projects should focus on the interim priorities set forth in RR P1, including the following actions:

- Provide a 200-year level of flood protection for existing urban and adjacent urbanizing areas (Water Code section 9600 et seq.).
- Improve the levees that protect aqueducts crossing the Delta and the freshwater pathway to Clifton Court Forebay, as depicted on Figure 7-6, to improve the reliability of these water supplies.
- Improve other Delta levees not specifically planned for ecosystem restoration to the FEMA HMP guidance level to ensure that the Delta's reclamation districts are eligible for public funding for emergency flood fighting, emergency repair, permanent restoration, and/or replacement of eligible damaged nonproject levees.
- Continue to fund and implement the Delta Levees Maintenance Subventions Program to maintain Delta levees.

In addition, the Delta Plan proposes creating a regional agency to assist with the planning, implementation, and financing of Delta flood risk reduction activities (see RR R2). Local levee-maintaining agencies have managed the financing and ongoing maintenance, rehabilitation, and repair of Delta levees, and have improved the levels of levee integrity, reducing overall Delta flood risk. Although the State has provided financial assistance over several decades, these programs have been funded primarily through State general obligation bonds, which face an uncertain future. The unencumbered bond funds that remain available for Delta levee projects total only $123 million.

An alternative funding mechanism could provide a more stable, long-term approach to funding in which local participation by all beneficiaries of flood risk management is more broadly incorporated. A regional flood risk management district with fee assessment authority could address a variety of Delta flood risk-related activities, including levee maintenance and improvements; regional flood management planning; flood facilities inspections; data collection; risk notification; and emergency preparedness planning, response, and mitigation. A regional flood risk management district could complement reclamation district activities. Because two ballot measures, Propositions 218 (1996) and 26 (2010) (discussed in Chapter 8), have raised the approval thresholds for new fees and taxes, the proposed regional assessment district will need to be broadly supported.

Delta Flood Management Facilities

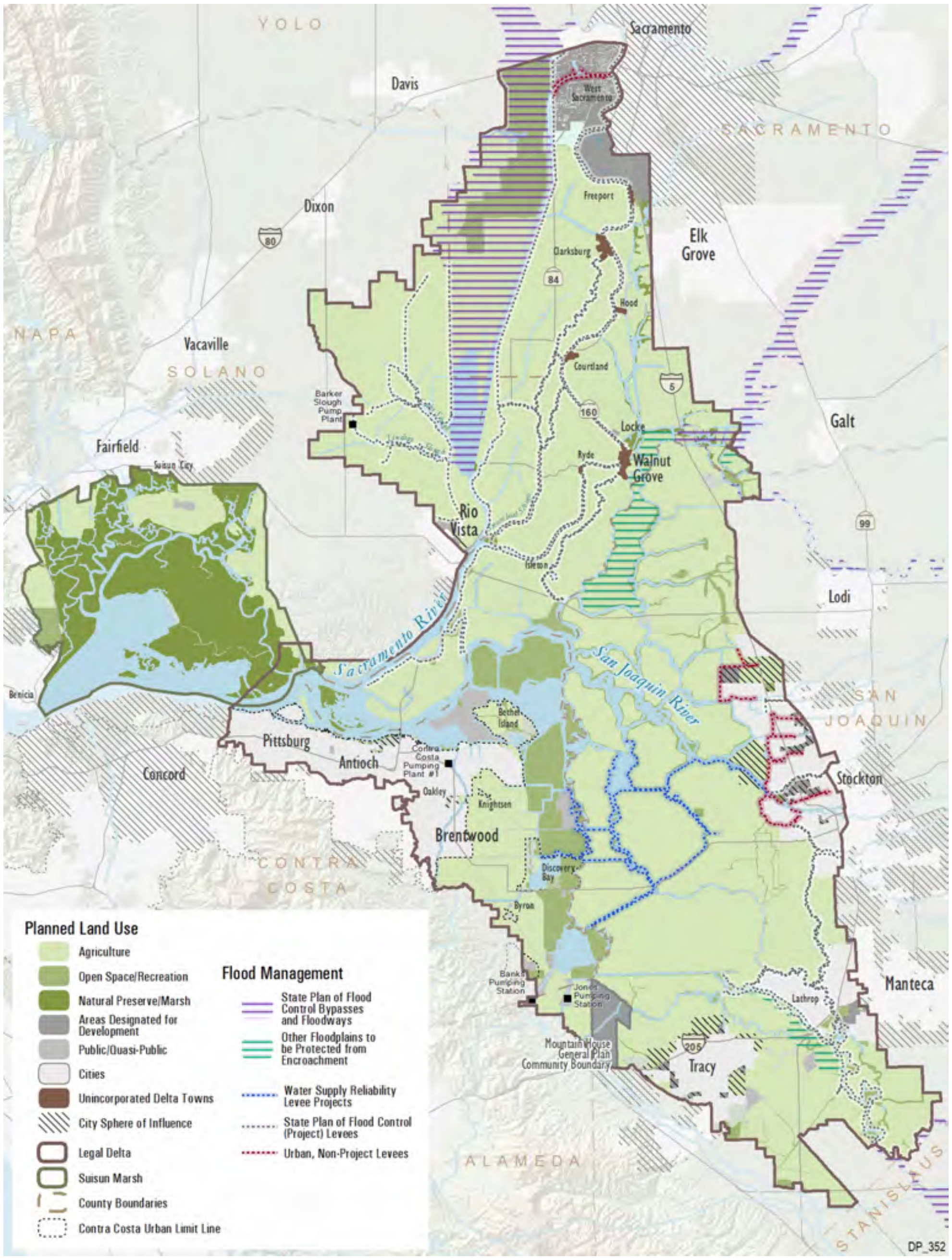


Figure 7-6

The map shows land uses designated by city and county general plans. Within cities' spheres of influences, the map shows land use designations proposed in city general plans, where available. In cases where cities have not proposed land uses within their spheres of influence, the map shows land uses designated by county general plans.

Sources: City of Benicia 2003, Contra Costa County 2008, Contra Costa County 2010, DWR 2011b, DWR 2011c, DWR 2011d, City of Fairfield 2008, Jones & Stokes 2007, City of Lathrop 2012, City of Manteca 2012, Mountain House Community Services District 2008, City of Rio Vista 2001, SACOG 2009, City of Sacramento 2008, Sacramento County 2011, Sacramento County 2012, Sacramento County 2013, San Joaquin County 2008a, San Joaquin County 2008b, Solano County 2008a, Solano County 2008b, South Delta Levee Protection and Channel Maintenance Authority 2011, City of Stockton 2011a, City of Stockton 2011b, City of Suisun City 2011, City of Tracy 2011a, City of Tracy 2011b, City of West Sacramento 2010, Yolo County 2010a, Yolo County 2010b.

Planning for Floodplain Land Use

The most important step in reducing risk to people in the Delta is to stop putting more people at risk behind levees that do not meet minimum modern standards for flood protection. Actions that increase the demand for higher public spending on flood risk reduction and exacerbate flood risk (for example, urbanizing floodprone areas) should be discouraged.

The DPC *Land Use and Resource Management Plan for the Primary Zone of the Delta* also includes important policies to limit development in floodprone areas of the Primary Zone:

> *Local governments shall carefully and prudently carry out their responsibilities to regulate new construction within flood hazard areas to protect public health, safety, and welfare. These responsibilities shall be carried out consistent with applicable regulations concerning the Delta, as well as the statutory language contained in the Delta Protection Act of 1992. Increased flood protection shall not result in residential designations or densities beyond those allowed under zoning and general plan designations in place on January 1, 1992, for lands in the Primary Zone. (DPC 2010)*

As noted in Chapter 5, the legacy community of Bethel Island warrants a special note because of its flood hazards. About 2,100 people reside on the island in about 1,300 residences concentrated on the south central shoreline and four mobile home parks. The island, which is below sea level, is surrounded by approximately 15 miles of levees, limiting the drainage of floodwaters in the event of a levee breach. A single road, Bethel Island Road, links the island to the mainland at the city of Oakley, complicating emergency response or evacuation in the event of flooding. Because developments on Bethel Island are proposed to be served by the Bethel Island Municipal Improvement District or other adjacent public services, the entire island is within the urban limit line adopted by Contra Costa voters in 2006. The high flood risks on the island and the restricted evacuation opportunities, however, indicate the island has greater hazards to lives and property than the Delta's other areas designated for development. For this reason, it is not excluded from the Delta Plan policy prohibiting new subdivisions unless adequate flood protection is provided. This is consistent with provisions of the Contra Costa County General Plan, which require that development other than a single home on existing parcels await resolution of several issues, including improvement of the community's public services, levees, and emergency evacuation routes.

As described in Chapter 5, urban residential, commercial, and industrial uses should be located in cities, other urban areas, and their spheres of influence, where strong levees can be provided, rather than in rural lands protected only by nonproject levees. Outside of these urban and urbanizing areas and the legacy communities, the Delta Plan prohibits major subdivisions of five or more parcels where 200-year flood protection is not available. Recognizing legacy community needs for incidental growth to maintain their unique cultural values, development within community boundaries should continue consistent with existing general plans, and federal and local flood protection laws. Appendix B provides maps of Delta community boundaries. Maintaining most of the Delta in rural, agricultural land use, as described in Chapter 5, complements policies that reduce the number of properties and the population exposed to high flood risks.

Finally, the participation of Delta counties and cities in the National Flood Insurance Program brings with it a requirement that all residential, commercial, agricultural, and industrial buildings comply with FEMA floodproofing standards, including elevating structure ground floors above the 100-year flood elevation. Examples of floodproofing are shown on Figure 7-7.

Examples of Floodproofing

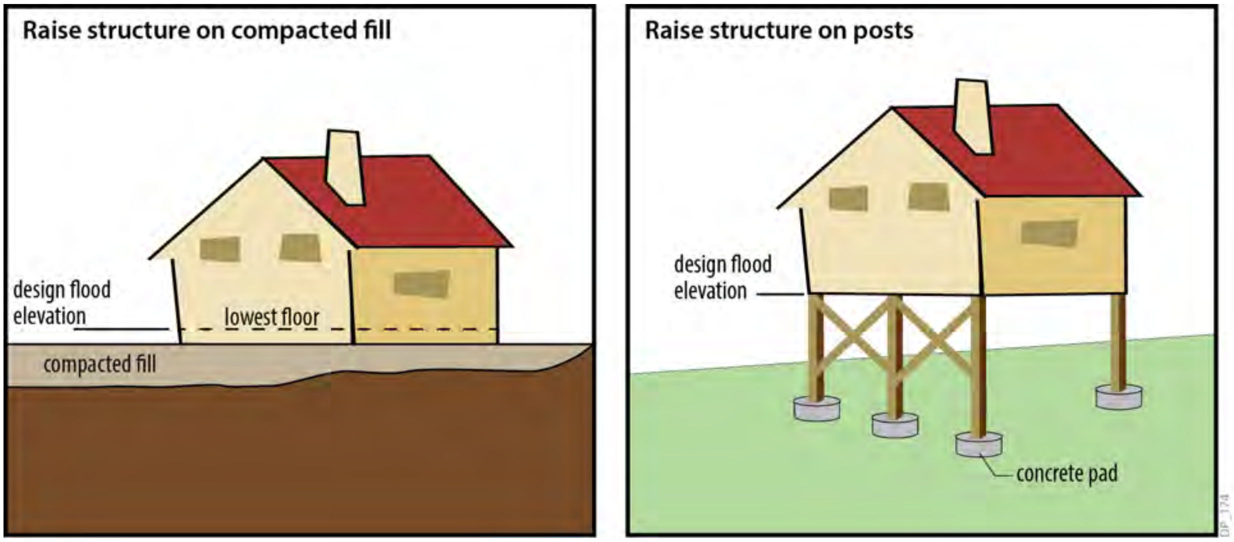


Figure 7-7

Floodproofing in accordance with the National Flood Insurance Program can be achieved through several methods. The illustration on the left shows an example of floodproofing by constructing the lowest floor within a structure above the design flood elevation. The illustration on the right shows floodproofing by raising the bottom of the structure above the design flood elevation.

Source: FEMA 1994; FEMA 2001

Emergency Preparedness and Response

Even with the best-engineered levees, channels, and floodways, a residual risk from flooding will always remain; flood risk can never be eliminated. Although investment in flood protection infrastructure can considerably reduce the likelihood of a catastrophic levee failure, failures are inevitable and will require well-coordinated and carefully developed emergency response efforts. To reduce response time and optimize effectiveness of response efforts, such plans need to leverage the unique capabilities of each agency with a mission in the Delta. This section provides an overview of the agencies and planning involved in emergency preparedness and response in the Delta.

Responsibilities for preparing for, declaring, and responding to flood emergencies are distributed among local, State, and federal agencies. Federal agencies with authority include USACE and FEMA. In California, State and local responsibilities fall to county offices of emergency services, local reclamation districts, Cal EMA, and DWR. In a Delta flood emergency, the response efforts by local and State emergency management professionals are guided by California's Standardized Emergency Management System (SEMS). SEMS was established by Government Code section 8607(a), and provides for effective management of multiagency and multijurisdictional emergencies in California, including flood emergencies. This system consists of five organizational levels, which are activated as necessary: (1) field response, (2) local government, (3) operational area, (4) regional, and (5) State. These levels are activated stepwise as the events warrant additional response and resources, meaning that each level of emergency responder contacts the next level above them should they deem the emergency beyond their capabilities to control. Federal resources are called upon if State resources are exhausted or additional assistance is needed. SEMS incorporates the functions and principles of the Incident Command System, the Master Mutual Aid Agreement, existing mutual aid systems, the operational area concept, and multiagency or interagency coordination. A detailed discussion of SEMS can be found in Cal EMA SEMS Guidelines (Cal EMA 2009). Local governments must use SEMS to be eligible for funding of their response-related personnel costs under State disaster assistance programs.

At the State level, Cal EMA's *California Emergency Plan* is the current guiding plan for all State emergencies. The California Emergency Plan incorporates and complies with the principles and requirements found in federal and State laws, regulations, and guidelines. Cal EMA typically defers to DWR for emergency management during floods. DWR emergency flood management actions are guided by its 2007 *Interim Flood Emergency Operations Plan*. DWR is in the process of developing its Delta Flood Emergency Preparedness Response and Recovery Program (EPRRP), which will be the overall guiding flood emergency management program for DWR activities for project and nonproject levees in the Delta. The Delta Flood EPRRP consists of three components: (1) the plan for flood emergency preparedness, response, and recovery actions in the Delta; (2) multiagency plan coordination, which coordinates DWR's plan with the plans of other Delta flood response agencies; and (3) response facilities implementation, which includes the development of flood emergency response facilities in the Delta.

At the federal level, USACE has a standing All-Hazards Emergency Response Plan and standing contracts for emergency response work in the Delta region, and is ready to assist the State, as requested through PL 84-99. These existing plans and procedures are considered in DWR's flood emergency operations plans and are a critical part of the Delta Flood EPRRP Plan. FEMA is responsible for coordinating the response of several federal agencies to a large natural disaster that overwhelms the resources of State and local authorities. The primary duty of FEMA is to ensure services to disaster victims through operational planning and integrated preparedness measures.

Following a flood disaster, various federal programs can provide disaster assistance. USACE has specific criteria concerning eligibility for assistance under PL 84-99. FEMA's HMP criteria must be met to be eligible for its assistance (Delta Stewardship Council Staff 2010b).

To further address emergency preparedness and response issues in the Delta, the Legislature passed SB 27 (Water Code section 12994.5) to develop and implement multi-hazard preparedness and response strategies for the Delta. This legislation required the Office of Emergency Services (now Cal EMA) to establish the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force. Led by Cal EMA, the task force consisted of representatives from the DPC, DWR, and representatives of the five Delta counties. The task force was directed to do the following:

- Make recommendations to the Secretary of Cal EMA relating to the creation of an interagency unified command system organizational framework, in accordance with the guidelines of the National Incident Management System and SEMS.
- Coordinate the development of a draft emergency preparedness and response strategy for the Delta region for submission to the Secretary of Cal EMA. Where possible, the strategy shall use existing interagency plans and planning processes of the involved jurisdictions and agencies that are members of the DPC.
- Develop and conduct all-hazard emergency response exercises and training in the Delta that are designed to test or facilitate implementation of regional coordination protocols.

The recommendations being prepared by the task force will likely play an important role in planning efforts for the Delta, and will be considered in the Delta Plan. When this Delta Plan was written, the task force recommendations had been approved by the Secretary of Cal EMA and forwarded to the Governor.

San Joaquin County has developed flood contingency maps and urban evacuation maps as part of its coordinated flood emergency planning efforts. These maps and plans could be used as an example by other Delta counties, and State and federal agencies to prepare a Delta-wide emergency response plan.

Liability Concerns

USACE and other federal agencies are generally afforded some immunity from liability for damages from flood events under the concept of sovereign immunity and provisions of the Flood Control Act of 1928 (33 United States Code section 702c). Congress provided immunity to federal agencies for some but not all tort damages. However, this immunity does not apply to nonfederal agencies.

As the risks of levee failure and corresponding damage increase, California's courts have generally exposed public agencies, and the State specifically, to significant financial liability for flood damages (DWR 2005). The most notable recent court decision on flood liability was the California Court of Appeal decision in *Paterno v. State of California* (2003) (113 Cal. App. 4th 998). The court found the State was liable for damages caused by the failure of a project levee on the Yuba River that the State did not design, build, or even directly maintain. This decision makes it possible that the State will ultimately be held responsible for the structural integrity of much of the federal flood control system in the Delta and Central Valley. The *Paterno v. State of California* decision will ultimately cost State taxpayers approximately $464 million in awarded damages.

In *Arreola v. County of Monterey* (2002) (99 Cal. App. 4th 722), the court held local agencies and the California Department of Transportation (Caltrans) liable for 1995 flood damages to property owners that resulted from a failure to properly maintain levees of the Pajaro River project.

The California *Draft FloodSAFE Strategic Plan* states, "Local communities are responsible for land use decisions, but generally have not been found liable for failure of the flood protection system. Continued local actions to approve development within floodplains may increase flood risk, even if levees and other flood protection improvements are made. This creates liability issues which the State is concerned about. Legislation passed in 2007 addresses the need to connect land use planning with diligent and factual consideration of flood risks for areas of proposed development" (DWR 2008a).

In 2007, the Legislature amended the Water Code to address local community liability for approving development in floodprone areas. It provides that "a city or county may be required to contribute its fair and reasonable share of the property damage caused by a flood to the extent that the city or county has increased the state's exposure to liability for property damage by unreasonably approving new development in a previously undeveloped area that is protected by a state flood control project" (Water Code sections 8307(a) and (b)).

Ultimately, however, it is important to note that the State does not own, operate, control, or maintain nonproject levees, and does not have authority to do so. The Delta levee subventions program grants financial assistance to local reclamation districts for their levees. The State conducts evaluations to make sure subventions program funds have been spent appropriately, but not to ensure the quality of the work or the stability or structural integrity of nonproject levees. Rather, the nonproject levees are the sole responsibility of the reclamation districts, and the State is not liable for damages caused by their failure.

POLICIES AND RECOMMENDATIONS

These policies and recommendations are based on the Council's core strategies for reducing flood risks in the Delta, which are:

- Improve emergency preparedness and response
- Finance and implement flood management activities
- Prioritize flood management investment
- Improve residential flood protection
- Protect and expand floodways, floodplains, and bypasses
- Integrate Delta levees and ecosystem function
- Limit liability

Reducing flood risks also relies on locating urban development in the Delta's cities where levees are stronger, as discussed in Chapter 5, and retaining rural lands for agriculture, so that development in the most floodprone areas is minimized.

Improve Emergency Preparedness and Response

To effectively and reliably reduce risks to people, property, and State interests in the Delta, a multifaceted strategy of coordinated emergency preparedness, appropriate land use planning, and prioritized investment in flood protection infrastructure is necessary (Water Code sections 85305(a) and 85306). Federal, State, and local governments—and Californians—must be prepared for a variety of emergency situations.

The recommendations prepared by the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force will likely play an important role in planning efforts for the Delta, and will be considered by the Council for incorporation in future updates of the Delta Plan.

Problem Statement

Levee failures and flooding can and will place human life and property in danger, and can have potentially significant implications for the State's water supply and infrastructure, and the health of the Delta ecosystem. Appropriate emergency preparedness and response planning and implementation activities need to be initiated.

Policies

No policies with regulatory effect are included in this section.

Recommendations

RR R1. Implement Emergency Preparedness and Response

The following actions should be taken by January 1, 2014, to promote effective emergency preparedness and response in the Delta:

- *Responsible local, State, and federal agencies with emergency response authority should consider and implement the recommendations of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force (Water Code section 12994.5). Such actions should support the development of a regional response system for the Delta.*
- *In consultation with local agencies, the California Department of Water Resources should expand its emergency stockpiles to make them regional in nature and usable by a larger number of agencies in accordance with California Department of Water Resources' plans and procedures. The California Department of Water Resources, as a part of this plan, should evaluate the potential of creating stored material sites by "over-reinforcing" west Delta levees.*
- *Local levee-maintaining agencies should consider developing their own emergency action plans, and stockpiling rock and flood-fighting materials.*
- *State and local agencies, and regulated utilities that own and/or operate infrastructure in the Delta should prepare coordinated emergency response plans to protect the infrastructure from long-term outages resulting from failures of the Delta levees. The emergency procedures should consider methods that also would protect Delta land use and ecosystem.*

Finance and Implement Local Flood Management Activities

The responsibility for securing funding for Delta levee maintenance, repairs, and improvements lies with the numerous local levee-maintaining agencies (primarily reclamation districts). Funding is generated through property assessments of local landowners and also is provided by the State under programs administered by DWR (the Delta Levees Special Flood Control Projects and Delta Levees Maintenance Subventions programs). These programs provide State matching funds for addressing Delta flood risk; however, many other entities that benefit from flood risk management are not assessed, nor do they contribute to maintenance and upkeep of Delta levees, including owners of regional infrastructure that crosses the Delta. The duty of providing for Delta flood risk management should be borne by all entities benefitting from these actions, and an equitable methodology of defining and apportioning assessments should be developed and implemented.

Local levee-maintaining agencies have managed the financing and ongoing maintenance, rehabilitation, and repair of Delta levees, and have improved the levels of levee integrity, reducing overall Delta flood risk. Although financial assistance has been provided by the State over several decades, these programs have most recently been funded exclusively through State general obligation bond financing, which faces an uncertain future. The development of an alternative funding mechanism and authority would provide for a more stable, long-term funding approach in which local participation by all beneficiaries of flood risk management is more broadly incorporated. Propositions 218 (1996) and 26 (2010) raised the approval thresholds for new fees and taxes; these thresholds may make it more difficult for a proposed regional assessment district to gain revenue authority.

The establishment of a regional flood risk management district with fee assessment authority could address a variety of Delta flood risk-related activities, including levee maintenance and improvements; regional flood management planning; flood facilities inspections; data collection; risk notification; and emergency preparedness planning, response, and mitigation. Establishing a more centralized and responsive entity could provide a mechanism for addressing issues at the individual district level and for the Delta region overall for the long term.

Problem Statement

No mechanism exists for ensuring that costs of levee maintenance are borne by all beneficiaries. Current financing of levee operations and maintenance is not well coordinated, and future funding sources are uncertain. Financing of local levee operations, maintenance, emergency preparedness and response, and related data collection and reporting efforts would benefit from greater coordination and integration.

Policies

No policies with regulatory effect are included in this section.

Recommendations

RR R2. Finance Local Flood Management Activities

The Legislature should create a Delta Flood Risk Management Assessment District with fee assessment authority (including over State infrastructure) to provide adequate flood control protection and emergency response for the regional benefit of all beneficiaries, including landowners, infrastructure owners, and other entities that benefit from the maintenance and improvement of Delta levees, such as water users who rely on the levees to protect water quality.

This district should be authorized to:

- *Identify and assess all beneficiaries of Delta flood protection facilities.*
- *Develop, fund, and implement a regional plan of flood management for both project and nonproject levees of the Delta, including the maintenance and improvement of levees, in cooperation with the existing reclamation districts, cities, counties, and owners of infrastructure and other interests protected by the levees.*
- *Require local levee-maintaining agencies to conduct annual levee inspections per the California Department of Water Resources subventions program guidelines, and update levee improvement plans every 5 years.*
- *Participate in the collection of data and information necessary for the prioritization of State investments in Delta levees consistent with RR P1.*
- *Notify residents and landowners of flood risk, personal safety information, and available systems for obtaining emergency information before and during a disaster on an annual basis.*
- *Potentially implement the recommendations of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force (Water Code section 12994.5) in conjunction with local, State, and federal agencies, and maintain the resulting regional response system and components and procedures on behalf of SEMS jurisdictions (reclamation district, city, county, and State) that would jointly implement the regional system in response to a disaster event.*
- *Identify and assess critical water supply corridor levee operations, maintenance, and improvements.*

RR R3. Fund Actions to Protect Infrastructure from Flooding and Other Natural Disasters

- *The California Public Utilities Commission should immediately commence formal hearings to impose a reasonable fee for flood and disaster prevention on regulated privately owned utilities with facilities located in the Delta. Publicly owned utilities should also be encouraged to develop similar fees. The California Public Utilities Commission, in consultation with the Delta Stewardship Council, the California Department of Water Resources, and the Delta Protection Commission, should allocate these funds among State and local emergency response and flood protection entities in the Delta. If a new regional flood management agency is established by law, a portion of the local share would be allocated to that agency.*
- *The California Public Utilities Commission should direct all regulated public utilities in their jurisdiction to immediately take steps to protect their facilities in the Delta from the consequences of a catastrophic failure of levees in the Delta, to minimize the impact on the State's economy.*
- *The Governor, by Executive Order, should direct State agencies with projects or infrastructure in the Delta to set aside a reasonable amount of funding to pay for flood protection and disaster prevention. The local share of these funds should be allocated as described above.*

Prioritize Flood Management Investment

A method is needed for prioritizing State funds for use in operating, maintaining, and improving Delta levees with a systemwide approach. Although the State has expended millions of dollars since the early 1970s on Delta levees, almost half of the Delta's acreage is not protected by levees that meet the HMP guidance today. Efforts by landowners, reclamation districts, and other parties using local resources to perform levee upgrades, beyond the standards that may be funded by the State, are encouraged and would be consistent with the goal of reducing Delta flood risk. The Delta Reform Act provides that activities of the Council in determining priorities for State investments in Delta levees do not increase the State's liability for flood protection in the Delta or its watershed.

Problem Statement

The Delta Reform Act (Water Code section 85306) requires the Delta Plan to recommend priorities for State investments in Delta levees, including project and nonproject levees. Currently, no comprehensive method exists to prioritize State investments in Delta levee operations, maintenance, and improvement projects. Without a prioritization methodology, the apportionment of public resources into levees may not occur in a manner that reflects a broader, long-term approach.

Policies

RR P1. Prioritization of State Investments in Delta Levees and Risk Reduction

(a) Prior to the completion and adoption of the updated priorities developed pursuant to Water Code section 85306, the interim priorities listed below shall, where applicable and to the extent permitted by law, guide discretionary State investments in Delta flood risk management. Key priorities for interim funding include emergency preparedness, response, and recovery as described in paragraph (1), as well as Delta levees funding as described in paragraph (2).

(1) Delta Emergency Preparedness, Response, and Recovery: Develop and implement appropriate emergency preparedness, response, and recovery strategies, including those developed by the Delta Multi-Hazard Task Force pursuant to Water Code section 12994.5.

(2) Delta Levees Funding: The priorities shown in the following table are meant to guide budget and funding allocation strategies for levee improvements. The goals for funding priorities are all important, and it is expected that over time, the California Department of Water Resources must balance achievement of those goals. Except on islands planned for ecosystem restoration, improvement of nonproject Delta levees to the Hazard Mitigation Plan (HMP) standard may be funded without justification of the benefits. Improvements to a standard above HMP, such as that set by the U.S. Army Corps of Engineers under Public Law 84-99, may be funded as befits the benefits to be provided, consistent with the California Department of Water Resources' current practices and any future adopted investment strategy.

Priorities for State Investment in Delta Integrated Flood Management Categories of Benefit Analysis

Goals	Localized Flood Protection	Levee Network	Ecosystem Conservation
1	Protect existing urban and adjacent urbanizing areas by providing 200-year flood protection.	Protect water quality and water supply conveyance in the Delta, especially levees that protect freshwater aqueducts and the primary channels that carry fresh water through the Delta.	Protect existing and provide for a net increase in channel-margin habitat.
2	Protect small communities and critical infrastructure of statewide importance (located outside of urban areas).	Protect floodwater conveyance in and through the Delta to a level consistent with the State Plan of Flood Control for project levees.	Protect existing and provide for net enhancement of floodplain habitat.
3	Protect agriculture and local working landscapes.	Protect cultural, historic, aesthetic, and recreational resources (Delta as Place).	Protect existing and provide for net enhancement of wetlands.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that involves discretionary State investments in Delta flood risk management, including levee operations, maintenance, and improvements. Nothing in this policy establishes or otherwise changes existing levee standards.

23 CCR Section 5012
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85300, 85305, and 85306, Water Code.

Recommendations

RR R4. Actions for the Prioritization of State Investments in Delta Levees

The Delta Stewardship Council, in consultation with the California Department of Water Resources, the Central Valley Flood Protection Board, the Delta Protection Commission, local agencies, and the California Water Commission, should develop funding priorities for State investments in Delta levees by January 1, 2015. These priorities shall be consistent with the provisions of the Delta Reform Act in promoting effective, prioritized strategic State investments in levee operations, maintenance, and improvements in the Delta for both levees that are a part of the State Plan of Flood Control and nonproject levees. Upon completion, these priorities shall be considered for incorporation into the Delta Plan.

The priorities should identify guiding principles, constraints, recommended cost share allocations, and strategic considerations to guide Delta flood risk reduction investments, supported by, at a minimum, the following actions to be conducted by the California Department of Water Resources, consistent with available funding:

- *An assessment of existing Delta levee conditions. This should include the development of a Delta levee conditions map based on sound data inputs, including, but not limited to:*
    - *Geometric levee assessment*
    - *Flow and updated stage-frequency analysis*
- *An island-by-island economics-based risk analysis. This analysis should consider, but not be limited to, values related to protecting:*
    - *Island residents/life safety*
    - *Property*
    - *Value of Delta islands' economic output, including agriculture*
    - *State water supply*
    - *Critical local, State, federal, and private infrastructure, including aqueducts, state highways, electricity transmission lines, gas/petroleum pipelines, gas fields, railroads, and deep water shipping channels*
    - *Delta water quality*
    - *Existing ecosystem values and ecosystem restoration opportunities*
    - *Recreation*
    - *Systemwide integrity*
- *An ongoing assessment of Delta levee conditions. This should include a process for updating Delta levee assessment information on a routine basis.*

This methodology should provide the basis for the prioritization of State investments in Delta levees. It should include, but not be limited to, the public reporting of the following items:

- *Tiered ranking of Delta islands, based on economics-based risk analysis values*
- *Delta levee conditions status report, including a levee conditions map*
- *Inventory of Delta infrastructure assets*

Improve Residential Flood Protection

To reduce the risk to lives, property, and State interests in the Delta, additional standards are needed to address new residential development. Sea level rise, subsidence, and new residential development combine to potentially put many more lives at risk. The policies in this section are designed to reduce risk while preserving the Delta's unique character and agricultural way of life. These policies should be construed as those required to provide the minimum level of flood protection, and should not be viewed as encouraging development in floodprone Delta areas. Flood insurance, and awareness of local emergency preparedness and response policies is strongly encouraged for all who live in floodprone areas of the Delta.

Consistent with existing law, urban development in the Primary Zone should remain prohibited. Urban development in the Secondary Zone should be confined to existing urban spheres of influence where the 200-year design standard will be fully implemented by 2025. The 2007 flood risk management legislation (SB 5) contained provisions affecting city and county responsibilities relating to local planning requirements, such as general plans, development agreements, zoning ordinances, tentative maps, and other actions (Government Code sections 65865.5, 65962, and 66474.5). Future land use decisions should not permit or encourage construction of significant numbers of new residences in the nonurban Delta. For the legacy communities in the Delta, structures developed in these areas are required to meet the legal standard of a 100-year minimum level of flood protection. However, developing and maintaining adequate flood protection remains difficult.

Problem Statement

Continued residential development without adequate flood protection increases risk to lives, property, and State interests in the Delta. Flood risks are expected to grow in light of anticipated climate change effects related to peak flows and sea level rise.

Policies

The appendices referred to in the policy language below are included in Appendix B of the Delta Plan.

RR P2. Require Flood Protection for Residential Development in Rural Areas

(a) New residential development of five or more parcels shall be protected through floodproofing to a level 12 inches above the 100-year base flood elevation, plus sufficient additional elevation to protect against a 55-inch rise in sea level at the Golden Gate, unless the development is located within:

(1) Areas that city or county general plans, as of May 16, 2013, designate for development in cities or their spheres of influence;

(2) Areas within Contra Costa County's 2006 voter-approved urban limit line, except Bethel Island;

(3) Areas within the Mountain House General Plan Community Boundary in San Joaquin County; or

(4) The unincorporated Delta towns of Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove, as shown in Appendix 7.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that involves new residential development of five or more parcels that is not located within the areas described in subsection (a).

23 CCR Section 5013
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85300, 85305, and 85306, Water Code.

Protect and Expand Floodways, Floodplains, and Bypasses

Local land use policies guiding development in floodways are not consistent across Delta counties. Floodways have not been established for many of the channels in the Delta by FEMA or by the CVFPB. In light of these inconsistencies, the Delta Plan addresses these issues and highlights the need for the protection of floodplains and floodways consistent with improved flood protection. Over the next 100 years, Delta floodways may expand and deepen because of sea level rise and changing precipitation patterns. Development in existing or potential future designated floodplain or bypass locations in the Delta or upstream of the Delta can permanently eliminate the availability of these areas for future floodplain usage. It is important to identify floodplain areas now for immediate protection and eventual integration into the flood protection system.

Problem Statement

The carrying capacity of the existing flood control system is diminished by encroachments into floodways, critical floodplains, and existing floodplain or bypass locations in the Delta. Local land use policies guiding development in floodways are not consistent across Delta counties. The existing system is already at suboptimal capacity. Expected changes in sea level rise and runoff patterns due to climate change are expected to exacerbate the problem.

Policies

RR P3. Protect Floodways

(a) No encroachment shall be allowed or constructed in a floodway, unless it can be demonstrated by appropriate analysis that the encroachment will not unduly impede the free flow of water in the floodway or jeopardize public safety.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that would encroach in a floodway that is not either a designated floodway or regulated stream.

23 CCR Section 5014
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85300, 85302, and 85305, Water Code.

RR P4. Floodplain Protection

(a) No encroachment shall be allowed or constructed in any of the following floodplains unless it can be demonstrated by appropriate analysis that the encroachment will not have a significant adverse impact on floodplain values and functions:

(1) The Yolo Bypass within the Delta;

(2) The Cosumnes River-Mokelumne River Confluence, as defined by the North Delta Flood Control and Ecosystem Restoration Project (McCormack-Williamson), or as modified in the future by the California Department of Water Resources or the U.S. Army Corps of Engineers (California Department of Water Resources 2010); and

(3) The Lower San Joaquin River Floodplain Bypass area, located on the Lower San Joaquin River upstream of Stockton immediately southwest of Paradise Cut on lands both upstream and downstream of the Interstate 5 crossing. This area is described in the Lower San Joaquin River Floodplain Bypass Proposal, submitted to the California Department of Water Resources by the partnership of the South Delta Water Agency, the River Islands Development Company, Reclamation District 2062, San Joaquin Resource Conservation District, American Rivers, the American Lands Conservancy, and the Natural Resources Defense Council, March 2011. This area may be modified in the future through the completion of this project.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that would encroach in any of the floodplain areas described in subsection (a).

(c) This policy is not intended to exempt any activities in any of the areas described in subsection (a) from applicable regulations and requirements of the Central Valley Flood Protection Board.

23 CCR Section 5015
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85020, 85300, 85302, and 85305, Water Code.

Recommendations

RR R5. Fund and Implement San Joaquin River Flood Bypass

The Legislature should fund the California Department of Water Resources and the Central Valley Flood Protection Board to evaluate and implement a bypass and floodway on the San Joaquin River near Paradise Cut that would reduce flood stage on the mainstem San Joaquin River adjacent to the urban and urbanizing communities of Stockton, Lathrop, and Manteca in accordance with Water Code section 9613(c).

RR R6. Continue Delta Dredging Studies

The current efforts to maintain navigable waters in the Sacramento River Deep Water Ship Channel and Stockton Deep Water Ship Channel, led by the U.S. Army Corps of Engineers and described in the Delta Dredged Sediment Long-Term Management Strategy (USACE 2007, Appendix K), should be continued in a manner that supports the Delta Plan and the coequal goals. Appropriate dredging throughout other areas in the Delta for maintenance purposes, or that would increase flood conveyance and provide potential material for levee maintenance or subsidence reversal should be implemented in a manner that supports the Delta Plan and coequal goals. Coordinated use of dredged material in levee improvement, subsidence reversal, or wetland restoration is encouraged.

RR R7. Designate Additional Floodways

The Central Valley Flood Protection Board should evaluate whether additional areas both within and upstream of the Delta should be designated as floodways. These efforts should consider the anticipated effects of climate change in its evaluation of these areas.

Integrate Delta Levees and Ecosystem Function

Setback levees can provide additional levee system stability, more complex land-water interface structure, and shaded riverine aquatic habitat that benefit ecosystem function in appropriate settings. They can also provide flood control benefits in those areas of the Delta not subject to strong tidal influences where channel capacity improvements can actually increase flood-carrying capacity. Not all locations are amenable or useful for setback levee placement. Each site should be investigated for its potential to provide ecological benefits consistent with levee integrity.

Problem Statement

Criteria for the development and implementation of setback levees in the Delta have not yet been developed by relevant agencies. These criteria are needed to provide appropriate guidance when considering setback levee siting and design. Currently, agencies have no consistent method for determining the appropriateness of setback levee incorporation as they relate to habitat enhancement and flood control benefit.

Policies

No policies with regulatory effect are included in this section.

Recommendations

RR R8. Develop Setback Levee Criteria

The California Department of Water Resources, in conjunction with the Central Valley Flood Protection Board, the California Department of Fish and Game, and the Delta Conservancy, should develop criteria to define locations for future setback levees in the Delta and Delta watershed.

Limit State Liability

The Delta Reform Act requires that the Delta Plan attempt to reduce risks to people, property, and State interests in the Delta by, among other things, recommending priorities for State investments in levee operation, maintenance, and improvements in the Delta, including project and nonproject levees (Water Code sections 85305, 85306, and 85307). The law expressly states that these provisions do not affect the liability of the State for flood protection in the Delta or its watershed (Water Code section 85032(j)). Consequently, no action taken by a State agency as required or recommended by, or otherwise in furtherance of, this Delta Plan shall affect State flood protection liability in the Delta or its watershed. Therefore, the Legislature should consider requiring an adequate level of flood insurance for residences, businesses, and industries in floodprone areas.

Problem Statement

As the risks of levee failure and corresponding damage increase, California courts have generally exposed public agencies and the State, specifically, to significant financial liability for flood damages. DWR's 2005 white paper recommends one way that the State should reduce its liability is to require houses and businesses to have flood insurance (DWR 2005).

Policies

No policies with regulatory effect are included in this section.

Recommendations

RR R9. Require Flood Insurance

The Legislature should require an adequate level of flood insurance for residences, businesses, and industries in floodprone areas.

RR R10. Limit State Liability

The Legislature should consider statutory and/or constitutional changes that would address the State's potential flood liability, including giving State agencies the same level of immunity with regard to flood liability as federal agencies have under federal law.

Timeline for Implementing Policies and Recommendations

Figure 7-8 lays out a timeline for implementing the policies and recommendations described in the previous section. The timeline emphasizes near-term and intermediate-term actions.

Timeline for Implementing Policies and Recommendations

TIMELINE **CHAPTER 7: Risk Reduction**

	ACTION (REFERENCE #)	LEAD AGENCY(IES)	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025
POLICIES	Prioritization of State investments in Delta levees and risk reduction (RR P1)	Council, DWR, CVFPB	●	
	Require flood protection for residential development in rural areas (RR P2)	Local agencies	●	●
	Protect floodways (RR P3)	CVFPB	●	●
	Floodplain protection (RR P4)	CVFPB	●	●
RECOMMENDATIONS	Implement emergency preparedness and response (RR R1)	Local, State, and federal agencies	●	
	Finance local flood management activities (RR R2)	Legislature, DPC	●	
	Fund actions to protect infrastructure from flooding and other natural disasters (RR R3)	PUC	●	
	Actions for the prioritization of State investments in Delta levees (RR R4)	Council, DWR, CVFPB	●	
	Fund and implement San Joaquin River Flood Bypass (RR R5)	Legislature, DWR, CVFPB	●	
	Continue Delta dredging studies (RR R6)	USACE	●	●
	Designate additional floodways (RR R7)	CVFPB	●	
	Develop setback levee criteria (RR R8)	DWR	●	
	Require flood insurance (RR R9)	Legislature	●	
	Limit State liability (RR R10)	Legislature	●	

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Agency Key:

Council: Delta Stewardship Council
CVFPB: Central Valley Flood Protection Board
DPC: Delta Protection Commission
DWR: California Department of Water Resources
PUC: California Public Utilities Commission
USACE: U.S. Army Corps of Engineers

Figure 7-8

Issues for Future Evaluation and Coordination

The following list of issues should be considered in future updates of the Delta Plan. These and other issues will need to be considered as additional information and materials become available. The various activities called for in this Delta Plan, as well as issues that arise from other planning efforts, such as the Central Valley Flood Protection Plan, will be considered. Additional areas of interest and concern related to flood risk in the Delta may deserve consideration in the development of future Delta Plan updates, including:

- **Reoperation of Upstream Reservoirs and Peak Flow Attenuation:** Reservoir operations upstream of the Delta can have substantial impacts on flood flows through the Delta; therefore, operation procedures among government agencies should be well coordinated and, where possible, focused more on flexibility to prevent flooding in the Delta. Water Code section 85309 directs DWR to develop a proposal to coordinate flood and water supply operations with appropriate State and federal agencies, and this shall be considered by the Council for future inclusion in the Delta Plan.
- **Utility Corridor Consolidation:** An attempt to consolidate infrastructure into "utility corridors" as facilities are added and upgraded over time should be further investigated to determine whether this can allow for better management of flood risk consequences to these critical assets.
- **State Highways and Sea Level Rise:** The Council will consult with Caltrans regarding the potential effects of climate change and sea level rise on the three state highways that cross the Delta (Water Code section 85307 (c)).

Science and Information Needs

The Delta system and its influencing factors are not static; therefore, research is needed to better understand dynamic issues such as climate change, seismicity, sea level rise, subsidence, and other areas. Continuing investigations into the science, engineering, and economic aspects of the Delta are critical to adaptively managing for expected and unexpected changes, and can provide decision makers and stakeholders with key information for future planning and decision making. Specifically, additional information will be needed in the following areas:

- The interaction between Delta levees and ecosystem function
- Sea level rise: impacts on, and incorporation into, flood risk reduction standards
- Climate change: effects of altered hydrology on levee system integrity
- Effects of seismicity on levee integrity
- Updated flood stage-probability functions
- Potential for subsidence reversal and carbon sequestration from growing native marsh plants
- Understanding the impacts on Delta flood management from upstream flood management infrastructure operations, including reservoir operations
- Technologies for assessing levee integrity

Efforts to address these needs and others that arise during Delta Plan implementation should be undertaken in a systematic fashion so that information developed and lessons learned can be incorporated into future Delta Plan updates.

Performance Measures

Development of informative and meaningful performance measures is a challenging task that will continue after the adoption of the Delta Plan. Performance measures need to be designed to capture important trends and to address whether specific actions are producing expected results. Efforts to develop and track performance measures in complex and large-scale systems like the Delta are commonly multiyear endeavors. The recommended output and outcome performance measures listed below are provided as examples and subject to refinement as time and resources allow. Final administrative performance measures are listed in Appendix E and will be tracked as soon as the Delta Plan is completed.

Output Performance Measures

- New residential development takes into account sea level rise in flood protection planning and development. (RR P2)
- Delta land acreage and the number of reclamation districts with levees below HMP are reduced. (RR P1)
- Freshwater aqueducts passing through the Delta and the primary freshwater channel pathways through the Delta are protected by levees that provide adequate protection against floods and other risks of failure. (RR P1)
- Responsible local, State, and federal agencies with emergency response authority implement the recommendations of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force (Water Code section 12994.5). (RR R1)
- DWR and the CVFPB construct a bypass and floodway on the San Joaquin River near Paradise Cut. (RR R5)

Outcome Performance Measures

- No lives are lost in the Delta as a result of flood emergencies, and economic damages associated with Delta flood emergencies decrease. (RR R1)
- Emergency response and recovery costs are eligible for FEMA reimbursement. (RR P1)
- Water deliveries to East Bay Municipal Utilities District, Contra Costa Water District, the CVP, and the SWP are not interrupted by floods or earthquakes. (RR P1)

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CHAPTER 8

Funding Principles to Support the Coequal Goals

ABOUT THIS CHAPTER

This chapter provides background information on federal, State of California (State), and local spending for water supply, water quality, flood management, and Delta ecosystem purposes. It proposes the development of a comprehensive finance plan to implement the Delta Plan. It also sets forth guiding principles for the development of a finance plan and proposes near-term funding for support of the Delta Protection Commission, Sacramento-San Joaquin Delta Conservancy, and the Delta Stewardship Council (Council).

A 5-year budget is included in Appendix M. And, as described in Chapter 2, successful implementation of the Delta Plan will depend upon many independent agency authorities and actions under the coordination and leadership of the Council.

CHAPTER 8

Funding Principles to Support the Coequal Goals

In establishing the coequal goals, the Delta Reform Act affirmatively reset spending priorities for the Delta ecosystem and water management. Inherent in the coequal goals is a new governance structure (primarily the Council), which the Legislature intended to have the "authority, responsibility, accountability, scientific support, and adequate *and secure funding to achieve these objectives*." The Council was directed to develop a long-term, legally enforceable management plan for the Delta, and in implementing the Delta Plan, to "direct actions across State agencies," in part through the establishment of an Interagency Implementation Committee. Additionally, as addressed in the preceding Delta Plan chapters, the Delta Reform Act set forth a number of policy objectives and other requirements for how the Delta Plan must be developed and what it must contain, ranging from broad guidance on types of projects the Plan should promote, to specific performance measures for evaluating progress on ecosystem restoration. Accordingly, the Council set forth several priority recommendations and regulatory policies, which together make up this Delta Plan.

The Delta Reform Act does not require the development of a financing plan for the implementation of the Delta Plan; however, given the current economic climate, recent uneven funding for water and ecosystem investment, and the critical nature of what is at stake should the coequal goals fail to be achieved, the Council affirmed the need for a financing plan and is committed to its development.

As the Public Policy Institute of California succinctly stated in its 2011 report on water management in California, "Although money alone is not sufficient for successful water management, it is necessary" (Public Policy Institute of California 2011). In introducing any discussion on financing, particularly in the public sector, it is necessary to acknowledge the political and economic context. America is currently suffering a severe recession, and California's economy has fared even worse. The State has experienced a multiyear budget crisis in which annual spending exceeds available revenue. As a result, financing infrastructure and new programs has become immensely challenging for State and local governments.

Today's economic conditions may limit the ability to adequately finance a full range of water and ecosystem improvements necessary to achieve the coequal goals in the near term. However, the planning timeframe for the Delta Plan runs to the year 2100, and decisions on long-term, sustainable financing for water, ecosystem, and flood protection cannot be delayed much longer without grave and expensive consequences. A long planning horizon allows near-term foundational steps to be taken now toward improving the situation and for implementing agencies to stage actions, policies, and projects over time consistent with an adaptive management structure based on science. Additionally, some activities to implement the Delta Plan are currently funded or can be undertaken with no additional cost, and many of the actions called for in the Delta Plan are certain to result in significant long-term cost savings.

Because of the complex nature of the policy issues and of certain funding and finance methods, a comprehensive and supportable Delta Plan finance plan will take time to develop. Thorough research is needed to identify entities that may be assessed user or stressor fees, determine appropriate levels for these fees, establish tiered fee structures, calculate the public benefits, and work through the legal implications of any financing strategy, including the practical effects of Propositions 218 and 26 on State and local financing mechanisms.

Background

Since the CALFED Bay-Delta Program was instituted in 1995 to restore ecological health and improve water management in the Delta, significant expenditures have been made in the Delta. An estimated $400 million has been spent annually, on average, by federal, State, and local water users.

Traditionally, the State has financed water infrastructure with general obligation bonds. These bonds were approved by the voters, and repayment is guaranteed by the State's general taxing power. With respect to State Water Project (SWP) debt, however, even though repayment was secured by taxes, general obligation bonds were paid back primarily by the water contractors. Since 2000, California voters have authorized $19.4 billion in water-related general obligation bonds spread over six separate bonds (LAO 2008). Several of these bonds authorize expenditures for a multitude of purposes, including assorted water projects, parkland acquisition, habitat restoration, and local assistance grants. One benefit of financing water projects with general obligation bonds is that any expenditure made for a public purpose is repaid by taxpayers, the primary beneficiaries. Currently, remaining fund balances for active bond accounts total approximately $2.2 billion out of the authorized total of $19.4 billion, only a portion of which is for Delta-related spending.

Table 8-1 summarizes the current balances for general obligation bonds by individual bond act related to water, ecosystem restoration, and flood protection. It is important to note that these remaining balances are not fungible; that is, statute generally dictates the specific types of projects or programs on which funds can be spent.

Currently scheduled for the November 2014 ballot, the Safe, Clean, and Reliable Drinking Water Supply Act of 2012 would authorize, upon voter approval, the issue and sale of $11.14 billion in general obligation bonds for financing drought relief projects, water supply reliability projects, Delta sustainability projects, water system improvements, watershed and conservation protection programs, groundwater protection and water quality projects, and water recycling projects. Key Delta projects include $2.25 billion for protection of water supplies from catastrophic levee failure, drinking water quality improvements, levee and flood control facilities improvements, lost property tax replacement, ecosystem restoration, and contaminants reduction.

General Obligation Bonds – California (as of January 2013)

TABLE 8-1

Bond Act (Year)	Authorized ($ Thousands)	Committed ($ Thousands)	Balance ($ Thousands)
Proposition 12 (2000)	2,024,486	6,189	18,456
Proposition 13 (2000)	2,103,000	1,823,874	279,126
Proposition 40 (2002)	2,471,600	16,556	26,536
Proposition 50 (2002)	3,382,630	0	0
Proposition 1E (2006)	4,090,000	4,024,354	65,646
Proposition 84 (2006)	5,388,000	5,080,840	307,160
Total	**$19,378,411**	**$17,221,349**	**$2,157,062**

Although general obligation bonds have been an important part of how California has funded water and ecosystem projects in the past, because of the uncertainty regarding voter approval of future bonds, a more sustainable and long-term financing approach for water, ecosystem, flood protection, and related projects is needed. As new revenue sources are developed, the use of revenue bonds may become more prevalent. For example, the SWP routinely sells and redeems revenue bonds to pay the costs of planning and construction, bond interest, and project operating expenses, as do many local agencies.

Federal-level expenditures in California in recent years have declined as grant programs for wastewater treatment in the late 1970s and 1980s expired, and flood control spending was reduced. It is likely that large federal budget deficits for the foreseeable future will preclude any increases in federal funds for California water projects.

Although State-level expenditures for water-related programs and projects in recent years have been almost entirely funded with general obligation bonds, this contrasts somewhat with the financing methods available to local agencies. Although many of these agencies have at times issued general obligation bonds and revenue bonds, it is more common for them to establish stable income streams by charging dedicated fees to ratepayers to pay the costs of infrastructure projects including water treatment and wastewater systems.

The ability of local agencies to fund flood control and stormwater projects, however, is specifically governed by the provisions of Proposition 218, approved by California voters in 1996. Under Proposition 218, direct voter approval by a majority of property owners or a two-thirds vote of the general public is required to raise funds for these purposes. Results of local Proposition 218 elections in recent years have been mixed, with some agencies gaining voter approval and others falling short of funding needed for local projects. For example, Sacramento voters successfully approved new assessments for flood control projects in 2007, but 1 year later, voters in Orinda (East Bay Area) and Burlingame (Bay Area) failed to approve new assessments for the same purpose (Public Policy Institute of California 2011).

A companion measure, Proposition 26, approved by voters in 2010, effectively raised voting requirements for most State and local regulatory fees from a simple majority to a two-thirds majority. Regulatory fees with a broad public purpose are considered taxes and are subject to a two-thirds vote of the Legislature. Local agencies are also required to seek a two-thirds vote of the general public.

The best available information shows that total annual federal, State, and local spending on water and wastewater treatment in California is approximately $24 billion (see Table 8-2). Operations, maintenance, and capital expenditures for water infrastructure consume significant economic resources in California. This total likely includes some overlap, but the expenditures are significant. Other sources cite higher expenditures for some of these categories. During development of the finance plan, this table will be updated to reflect the most recent data.

Bay Delta Conservation Plan

Described in various sections of this Delta Plan, the Bay Delta Conservation Plan (BDCP) is a massive water and ecosystem public works planning process under way in the Delta. The Council supports the completion of the BDCP according to the provisions set forth in the Delta Reform Act. The scope or type of any water facility improvements, related Delta ecosystem mitigation, and other habitat improvements to be included is very preliminary at this time. The BDCP's ongoing planning costs are currently funded by State and federal water contractors. Currently available information from the BDCP indicates that, once it is completed, the first 5 years of implementation will require between $5.7 and $5.9 billion total for capital outlay, of which approximately $5.2 billion is for water conveyance. Additionally, the BDCP estimates that $3.6 billion total plus $46 million annually will be required for Delta ecosystem

Annual Budgets/Expenditures in California for Selected Agencies

TABLE 8-2

Agency	Budget/Expenditures Operating ($ Millions)	 Capital ($ Millions)	Source
Local cities, counties, and special districts water	10,100	2,000	California State Controller 2011a, 2011b, 2011c
Local cities, counties, and special districts wastewater	5,400	1,100	California State Controller 2011a, 2011b, 2011c
Local cities, counties, and special districts flood control	1,000	300	California State Controller 2011a, 2011b, 2011c
California Department of Water Resources	2,267	232	California Department of Finance 2012
State Water Resources Control Board	714		California Department of Finance 2012
California Department of Fish and Wildlife	381		California Department of Finance 2012
Bureau of Reclamation	300		Bureau of Reclamation 2008
U.S. Army Corps of Engineers	100	100	U.S. Army Corps of Engineers 2008
Total	**$20,262**	**$3,732**	

restoration (BDCP Steering Committee 2010). The BDCP will include a funding plan that will address estimated implementation costs and sources of funding that will be relied upon to cover these costs. The sidebar, Bay Delta Conservation Plan Costs and Existing Funding Sources, provides additional background information about the BDCP.

Overview of Current State and Federal Delta-related Expenditures

The CALFED Bay-Delta Program was incorporated into the Council in 2010. However, some program elements endure because bond funds are dedicated by law for CALFED purposes. Additionally, the CALFED program is still referenced in federal statutes. For these reasons, an annual cross-cut budget showing State and federal expenditures for active CALFED programs and projects is developed each January.

Because the cross-cut budget includes State and federal expenditure details on all the CALFED programs, those data can be summarized to show expenditures for program elements displayed in the budget. The results are shown in Table 8-3.

Annual State and Federal Expenditures in California by Program Element (2012–2013)

TABLE 8-3

Program Element	California	Federal	Total
Governance	$21,145,596	$20,490,000	$41,635,596
Water Supply Reliability	$161,523,833	$18,774,000	$180,297,833
Ecosystem Restoration	$64,119,524	$92,275,000	$156,394,524
Water Quality	$6,368,631	$5,000,000	$11,368,631
Risk Reduction/Levee Integrity	$8,949,231	$45,560,000	$54,509,231
Total	**$262,106,815**	**$182,099,000**	**$444,205,815**

BAY DELTA CONSERVATION PLAN COSTS AND EXISTING FUNDING SOURCES

Potential future funding sources for the BDCP will likely compete with funding required for implementation of some elements of the Delta Plan, and for the plans and projects of State, federal, and local agencies. The Council does not consider any funding source to be solely available for the BDCP, or for any other program or plan. They are solely considered to be options at this stage.

Based on current information from the BDCP, the approximate costs of a facility and related ecosystem improvements needed for State and federal approval are approximately $15.8 to $16.7 billion in capital costs and an additional $4.9 to $5.6 billion in operating costs over the 50-year permit period. These costs are divided among the BDCP's four primary functions—water conveyance, habitat restoration, management of other stressors, and program oversight—as shown in the table below. The Council notes that preliminary cost estimates are just that: preliminary. Going forward, refined estimates will be required to complete this planning process.

Options for BDCP Funding

The BDCP is premised on the pledge of participating State and federal water contractors to pay the full cost of any new Delta export facility and the associated Delta ecosystem mitigation required to meet the requirements imposed on the BDCP by federal and State laws. Habitat and ecosystem restoration activities, beyond mitigation requirements, are considered to provide a general benefit to the State and should be funded accordingly.

Prior to completion of the BDCP and a full understanding of the Delta ecosystem improvements related to the BDCP, it is impossible to project the detailed funding options that might be necessary. However, it is highly likely that user fees, revenue bonds, and sources other than the State General Fund will be the primary sources of funding.

Summary of BDCP Costs and Existing Funding Sources ($ millions)

	Bay Delta Conservation Plan[a]		
Program Function	**Capital Costs**	**Operating Costs**	**Total**
Water Conveyance[b]	$12,691	$2,936	$15,627
Habitat Restoration[c]	$3,108–$4,009	$346–$437	$3,454–$4,446
Other Stressors[c]	$12–$15	$1,213–$1,679	$1,225–$1,694
Program Oversight[c]		$404–$548	$404–$548
Total	$15,811–$16,715	$4,899–$5,600	$20,710–$22,315

[a] Over 50-year permit period [b] Midpoint cost estimate [c] Range of low-high estimate given

Source: BDCP Steering Committee, 2010

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A Delta Finance Plan

The Council proposes to initiate development of a finance plan following adoption of the Delta Plan. This process will require the active participation of the Interagency Implementation Committee described in Chapter 2. Financing and funding mechanisms to be considered in developing the finance plan are included in Appendix N.

Guiding Principles

A finance plan to fund the Delta Plan should follow these principles:

- The finance plan should first consider currently available funds that can legally support expenditures for Delta-related projects. Spending priorities should be established that address near-term funding requirements as contained in this Delta Plan.
- Implementation of the Delta Plan will undoubtedly require an array of funding sources, including new funding sources and new statutory authority. Broad-based financing and diversity in funding sources will enhance revenue stability. Likewise, State and federal funds for activities that implement the Delta Plan must be reserved for public benefits not otherwise required for project mitigation or required by law for other purposes. Appendix N describes potential funding sources.
- The Delta Plan recommends many projects that have multiple benefits; this increases opportunities to blend fund sources and builds on the tradition of past investments in multipurpose water projects with diversified fund sources.
- A clear and analytically based methodology for assessing public benefits should be evaluated and implemented.
- Targeted finance plans should be developed for major Delta Plan plans and projects (ecosystem restoration, flood risk reduction, regional water supply investments, science, administration, and water conveyance). Beneficiaries and stressors should be identified in each of these areas, and user fees should be developed to match these stressors and beneficiaries with planned investments in each of these areas.
- Economic and financial analyses should be done as early as possible during the planning of large capital projects. This will assist agencies in the design of cost-effective projects and will help ensure that the projects are actually completed and implemented. Financial analyses should account for all of the costs of a project, both direct and indirect, including acquisition, planning, capital and interest, mitigation, science and monitoring, and operations and maintenance.

User Fees

- User fees, including beneficiary fees and stressor fees, are essential and should be established to support the coequal goals and the implementation of the Delta Plan.
- The "beneficiaries pay" principle is a common financing approach for water projects. The challenge is to determine the beneficiaries and design a cost-allocation method scaled to the benefit.
- A companion principle to "beneficiaries pay" is "stressors pay." Human activity that causes negative operational or environmental impacts should be assessed a fee, or otherwise charged, to repair the damage. An example of the stressors pay approach might be a surcharge on pesticides that are found to negatively impact the Delta ecosystem. Capital construction projects, whether for water reliability purposes or Delta ecosystem improvements, should be undertaken simultaneously with the development of beneficiary and user fees. Delay in establishing beneficiaries/stressors fee structures will inevitably delay any needed capital improvement projects. The development of information related to financing (such as the identification of beneficiaries and stressors, and detailed financing scenarios) should be undertaken simultaneously with the development of major capital decisions so that it can inform planning efforts.

- The finance plan should include mechanisms to ensure that user fees are legally dedicated to their intended purpose. Given State and federal budget constraints, statutory protections must be enacted to assure users that their assessments will not be diverted to other purposes.
- The finance plan should include opportunities to generate revenue when planning projects, where possible, to ensure long-term financing stability.
- To the extent possible, user fees should be based on the amount of water used or, for stressors, the volume of contaminants discharged. Tiered fee structures also should be explored where applicable.
- Long-term, stable funding approaches, such as the Delta Flood Risk Management Assessment District recommended in Chapter 7 or other beneficiary user fees, should be established to support the Delta Levees Maintenance Subventions Program, Delta Levees Special Flood Control Projects Program, and implementation of the Central Valley Flood Protection Plan.

Near-term and Annual Funding Requirements

The following items describe activities that must be addressed and funded as soon as possible. They describe the urgent need to immediately address the steps needed to achieve the coequal goals, begin implementation of the Delta Plan, and establish annual funding for key Delta agencies:

- **Urgent expenditures for water supply reliability and ecosystem protection.** Immediate steps should be taken to protect the existing Delta water export system from flood risks and carry out ecosystem improvements being implemented pursuant to existing mitigation commitments of the SWP and the Central Valley Project. Those immediate needs are discussed in the various chapters of the Delta Plan.
- **Create a regional Delta Flood Risk Management Assessment District.** The Legislature should create a regional district with the authority to assess fees on Delta levee beneficiaries, including landowners, infrastructure owners, and other entities, to fund flood control protection, including levee maintenance and improvement, and emergency response, as recommended in Chapter 7.
- **Fund a strong Delta Science Program.** Funding is needed for continued operation of the Independent Science Board, development of the proposed Delta Science Plan, the State's share of the Interagency Ecological Program, and other activities that support a strong science foundation for Delta Plan implementation. Funding for the Interagency Ecological Program should continue from participating agencies.
- **Fund urban and agricultural water management plans.**
- **Continue the existing operational duties imposed by the Delta Reform Act.** The Act created the Council (which includes the Delta Science Program and Independent Science Board) and the Sacramento-San Joaquin Delta Conservancy, and modified the duties of the Delta Protection Commission. Future estimated annual operating costs for these agencies are provided in Appendix M.
- **Fees for services.** The Legislature should grant authority to the Council to assess fees to cover the costs of providing specified services related to covered actions, specifically early consultations and reviewing appeals of consistency certifications.

POLICIES AND RECOMMENDATIONS

Administrative performance measures for the following recommendations can be found in Appendix E.

FP R1 Conduct Current Spending Inventory

An inventory of current State and federal spending on programs and projects that do or may achieve the coequal goals will be conducted. Data sources to be used include the CALFED cross-cut budget, State bond balance reports, and the annual State budget, among others. Consideration will be given to selecting an independent agency (which could include a nongovernmental organization) to conduct the inventory.

FP R2 Develop Delta Plan Cost Assessment

Costs will be assigned to the projects and programs proposed in the Delta Plan (Chapters 2 through 7), and sources of funding will be identified.

FP R3 Identify Funding Gaps

Current State and federal funding gaps will be identified that are determined to hinder progress toward meeting the coequal goals.

Timeline for Implementing Recommendations

Figure 8-1 lays out a timeline for implementing the recommendations described in the previous section.

Timeline for Implementing Recommendations

TIMELINE **CHAPTER 8: Funding Principles to Support the Coequal Goals**

	ACTION (REFERENCE #)	LEAD AGENCY	NEAR TERM 2012–2017	INTERMEDIATE TERM 2017–2025
RECOMMENDATIONS	Conduct current spending inventory (FP R1)	Council	●	
	Develop Delta Plan cost assessment (FP R2)	Council	●	
	Identify funding gaps (FP R3)	Council	●	

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Agency Key:

Council: Delta Stewardship Council

Figure 8-1

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Glossary

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Glossary

The first section of this glossary provides definitions that appear in 23 California Code of Regulations section 5001. The second section provides definitions and explanations of key terms, acronyms, and abbreviations used in the Delta Plan.

Definitions in 23 California Code of Regulations Section 5001

As used in this division, the terms listed below shall have the meanings noted:

(a) *"Adaptive management" means a framework and flexible decision-making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives.*

(b) *"Agricultural water management plan" means a plan prepared, adopted, and updated by an agricultural water supplier pursuant to the Agricultural Water Management Planning Act, Water Code section 10800 et seq.*

(c) *"Agricultural water supplier" under the Water Code refers to both agricultural retail water suppliers and agricultural wholesale water suppliers, but not the California Department of Water Resources or the United States Bureau of Reclamation, and includes both of the following:*

> (1) *A water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding recycled water; and*
>
> (2) *A water supplier or contractor for water, regardless of the basis of the water right, that distributes or sells water for ultimate resale to customers.*

(d) *"Base Flood" means the flood that has a 1-percent probability of being equaled or exceeded in any given year (also referred to as the 100-year flood).*

(e) *"Base Flood Elevation" (BFE) means the water surface elevation associated with the base flood.*

(f) *"Best available science" means the best scientific information and data for informing management and policy decisions. Best available science shall be consistent with the guidelines and criteria found in Appendix 1A.*

(g) *"Central Valley Flood Protection Board" or "Board" means the Central Valley Flood Protection Board (formerly The Reclamation Board) of the Resources Agency of the State of California as provided in Water Code section 8521.*

(h) *"Coequal goals" means the two goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The coequal goals shall be achieved in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place. In addition, "achievement" for the purpose of determining whether a plan, program, or project meets the definition of a ''covered action'' under section 5001(j) is further defined as follows:*

> (1) *"Achieving the coequal goal of providing a more reliable water supply for California" means all of the following:*
>
> > (A) *Better matching the state's demands for reasonable and beneficial uses of water to the available water supply. This will be done by promoting, improving, investing in, and implementing projects and programs that improve the resiliency of the state's water systems, increase water efficiency and conservation, increase water recycling and use of advanced water technologies, improve groundwater management, expand storage, and improve Delta conveyance and operations. The evaluation of progress toward improving reliability will take into account the inherent variability in water demands and supplies across California;*

(B) Regions that use water from the Delta watershed will reduce their reliance on this water for reasonable and beneficial uses, and improve regional self-reliance, consistent with existing water rights and the State's area-of-origin statutes and Reasonable Use and Public Trust Doctrines. This will be done by improving, investing in, and implementing local and regional projects and programs that increase water conservation and efficiency, increase water recycling and use of advanced water technologies, expand storage, improve groundwater management, and enhance regional coordination of local and regional water supply development efforts; and

(C) Water exported from the Delta will more closely match water supplies available to be exported, based on water year type and consistent with the coequal goal of protecting, restoring, and enhancing the Delta ecosystem. This will be done by improving conveyance in the Delta and expanding groundwater and surface storage both north and south of the Delta to optimize diversions in wet years when more water is available and conflicts with the ecosystem are less likely, and limit diversions in dry years when conflicts with the ecosystem are more likely. Delta water that is stored in wet years will be available for water users during dry years, when the limited amount of available water must remain in the Delta, making water deliveries more predictable and reliable. In addition, these improvements will decrease the vulnerability of Delta water supplies to disruption by natural disasters, such as, earthquakes, floods, and levee failures.

(2) "Achieving the coequal goal of protecting, restoring, and enhancing the Delta ecosystem" means successfully establishing a resilient, functioning estuary and surrounding terrestrial landscape capable of supporting viable populations of native resident and migratory species with diverse and biologically appropriate habitats, functional corridors, and ecosystem processes.

(3) "Achieving the coequal goals in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place" means accepting that change, including change associated with achieving the coequal goals, will not cease, but that the fundamental characteristics and values that contribute to the Delta's special qualities and that distinguish it from other places can be preserved and enhanced while accommodating these changes. In this regard, the following are core strategies for protecting and enhancing the unique values that distinguish the Delta and make it a special region:

(A) Designate the Delta as a special place worthy of national and state attention;

(B) Plan to protect the Delta's lands and communities;

(C) Maintain Delta agriculture as a primary land use, a food source, a key economic sector, and a way of life;

(D) Encourage recreation and tourism that allow visitors to enjoy and appreciate the Delta and that contribute to its economy;

(E) Sustain a vital Delta economy that includes a mix of agriculture, tourism, recreation, related industries and business, and vital components of state and regional infrastructure; and

(F) Reduce flood and other risks to people, property, and other interests in the Delta.

(i) "Commercial recreational visitor-serving uses" means a land use designation that describes visitor-serving uses, accommodations, restaurants, and shops, that respect the rural character and natural environmental setting. These uses also include campgrounds and commercial recreational facilities.

(j)(1) "Covered action" means a plan, program, or project that meets all of the following criteria (which are collectively referred to as covered action screening criteria):

(A) Is a "project," as defined pursuant to section 21065 of the Public Resources Code;

(B) Will occur, in whole or in part, within the boundaries of the Delta or Suisun Marsh;

(C) Will be carried out, approved, or funded by the State or a local public agency;

(D) Will have a significant impact on achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and State interests in the Delta; and

(E) Is covered by one or more provisions of the Delta Plan, which for these purposes, means one or more of the regulatory policies contained in Article 3.

(2) "Covered action" does not include any plan, program, or project that is exempted pursuant to Water Code section 85057.5(b).

(3) A State or local public agency that proposes to carry out, approve, or fund a plan, program, or project that may be subject to this Chapter must determine whether that proposed plan, program, or project is a covered action. That determination, which is subject to judicial review, must be reasonable, made in good faith, and consistent with the Delta Reform Act and this Chapter.

(4) Nothing in the application of the definition of a "covered action" shall be interpreted to authorize the abrogation of any vested right whether created by statute or by common law.

(k) "Delta" means the Sacramento-San Joaquin Delta as defined in section 12220 of the Water Code and the Suisun Marsh, as defined in section 29101 of the Public Resources Code.

(l) "Delta Plan" means the comprehensive, long-term management plan for the Delta to further the achievement of the coequal goals, as adopted by the Delta Stewardship Council in accordance with the Sacramento-San Joaquin Delta Reform Act of 2009.

(m) "Designated Floodway" means those floodways, as defined in California Code of Regulations, Title 23, section 4(i), under the jurisdiction of the Central Valley Flood Protection Board.

(n) "Encroachment" means any obstruction or physical intrusion by construction of works or devices, planting or removal of vegetation, or by any means for any purpose, into or otherwise affecting a floodway or floodplain.

(o) "Enhancement" or "enhancing," for purposes of section 5001(h)(2), means improving existing desirable habitat and natural processes. Enhancement may include, by way of example, flooding the Yolo Bypass more often to support native species or to expand or better connect existing habitat areas. Enhancement includes many fish and wildlife management practices, such as managing wetlands for waterfowl production or shorebird habitat, installing fish screens to reduce entrainment of fish at water diversions, or removing barriers that block migration of fish to upstream spawning habitats.

(p) "Feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors.

(q) "Floodplain" means any land area susceptible to being inundated by flood waters from any source.

(r) "Floodplain values and functions" has the same meaning as set forth in 33 Code of Federal Regulations section 320.4(l)(1).

(s) "Floodproofing" means any combination of structural and nonstructural additions, changes, or adjustments appropriate for residential structures, which reduce or eliminate risk of flood damage to real estate, improved real property, or structures with their contents.

(t) "Floodway" means the portion of the floodplain that is effective in carrying flow (that is, the channel of a river or other watercourse and the adjacent land areas that convey flood waters).

(u) "Government-sponsored flood control program to reduce risks to people, property, and State interests in the Delta" means any State or federal strategy, project, approval, funding, or other effort that is intended to reduce the likelihood and/or consequences of flooding of real property and/or improvements, including risks to people, property, and State interests in the Delta, that is carried out pursuant to applicable law, including, but not limited to the following:

(1) State Water Resources Law of 1945, Water Code section 12570 et seq.;

(2) Sacramento-San Joaquin River Flood Control Projects (Flood Control Act of 1941, P.L. 77-228);

(3) Local Plans of Flood Protection prepared pursuant to the Local Flood Protection Planning Act (Water Code section 8200 et seq.), that are consistent with the Central Valley Flood Protection Plan pursuant to Water Code section 9612;

(4) Central Valley Flood Protection Plan (Water Code section 9600 et seq.);

(5) Subventions Program, Special Projects Program (Water Code section 12300 et seq.);

(6) Way Bill 1973-Subventions Program, Special Projects Program (Water Code section 12980 et seq.);

(7) Central Valley Flood Protection Board Authority (California Code of Regulations, Title 23, Division 1); and

(8) National Flood Insurance Program (National Flood Insurance Act of 1968, 42 U.S.C. 4001 et seq., P.L. 90-448).

(v) "Nonnative invasive species," for purposes of section 5009, means species that establish and reproduce rapidly outside of their native range and may threaten the diversity or abundance of native species through competition for resources, predation, parasitism, hybridization with native populations, introduction of pathogens, or physical or chemical alteration of the invaded habitat.

(w) "Nonproject levee" means a local levee owned or maintained by a local agency or private owner that is not a project facility under the State Water Resources Law of 1945, Chapter 1 (commencing with Water Code section 12570) and Chapter 2 (commencing with section 12639 of Part 6 of the Water Code).

(x) "Project levee" means a federal flood control levee that is a project facility under the State Water Resources Law of 1945, Chapter 1 (commencing with Water Code section 12570) and Chapter 2 (commencing with section 12639 of Part 6 of the Water Code).

(y) "Proposed action" means a plan, program, or project that meets the covered action screening criteria listed in section 5001(j)(1)(A) through (D). Proposed action is also a "covered action," and therefore subject to compliance with the regulatory policies contained in Articles 2 and 3—if the proposed action meets the covered action screening criterion listed in section 5001(j)(1)(E).

(z) "Protection" or "protecting," for purposes of section 5001(h)(2), means preventing harm to the ecosystem, which could include preventing the conversion of existing habitat, the degradation of water quality, irretrievable conversion of lands suitable for restoration, or the spread of invasive nonnative species.

(aa) "Regulated stream" means those streams identified in Table 8.1 of California Code of Regulations, Title 23, section 112, under the jurisdiction of the Board.

(bb) "Restoration" or "restoring," for purposes of section 5001(h)(2), has the same meaning as in Water Code section 85066. Restoration actions may include restoring interconnected habitats within the Delta and its watershed, restoring more natural Delta flows, or improving ecosystem water quality.

(cc) "Setback levee" means a new levee constructed behind an existing levee which allows for removal of a portion of the existing levee and creation of additional floodplain connected to the stream. In the Delta, a "setback levee" may not necessarily result in removal of the existing levee.

(dd) "Significant impact" for the purpose of determining whether a project meets the definition of a "covered action" under section 5001(j)(1)(D) means a substantial positive or negative impact on the achievement of one or both of the coequal goals or the implementation of a government-sponsored flood control program to reduce risks to people, property, and State interests in the Delta, that is directly or indirectly caused by a project on its own or when the project's incremental effect is considered together with the impacts of other closely related past, present, or reasonably foreseeable future projects. The following categories of projects will not have a significant impact for this purpose:

(1) "Ministerial" projects exempted from CEQA, pursuant to Public Resources Code section 21080(b)(1);

(2) "Emergency" projects exempted from CEQA, pursuant to Public Resources Code section 21080(b)(2) through (4);

(3) Temporary water transfers of up to one year in duration. This provision shall remain in effect only through December 31, 2016, and as of January 1, 2017, is repealed, unless the Council acts to extend the provision prior to that date. The Council contemplates that any extension would be based upon the California Department of Water Resources' and the State Water Resources Control Board's participation with stakeholders to recommend measures to reduce procedural and administrative impediments to water transfers and protect water rights and environmental resources by December 31, 2016. These recommendations should include measures to address potential issues with recurring transfers of up to 1 year in duration and improved public notification for proposed water transfers;

(4) Other projects exempted from CEQA, unless there are unusual circumstances indicating a reasonable possibility that the project will have a significant impact under Water Code section 85057.5(a)(4), as further defined by this section. Examples of unusual circumstances could arise in connection with, among other things:

(A) Local government general plan amendments for the purpose of achieving consistency with the Delta Protection Commission's Land Use and Resource Management Plan; and,

(B) Small-scale habitat restoration projects, as referred to in CEQA Guidelines, section 15333 of Title 14 of the California Code of Regulations, proposed in important restoration areas, but which are inconsistent with the Delta Plan's policy related to appropriate habitat restoration for a given land elevation (section 5006 of this Chapter).

(ee) "Urban area" means a developed area in which there are 10,000 residents or more.

(ff) "Urbanizing area" means a developed area or an area outside of a developed area that is planned or anticipated to have 10,000 residents or more within the next 10 years.

(gg) "Urban water management plan" means a plan prepared, adopted, and updated by an urban water supplier pursuant to the Urban Water Management Planning Act, Water Code section 10610 et seq.

(hh) "Urban water supplier" refers to both "urban retail water suppliers" and "urban wholesale water suppliers":

(1) "Urban retail water supplier" means a water supplier, either publicly or privately owned, that directly provides potable municipal water to more than 3,000 end users or that supplies more than 3,000 acre-feet of potable water annually at retail for municipal purposes.

(2) "Urban wholesale water supplier" means a water supplier, either publicly or privately owned, that provides more than 3,000 acre-feet of potable water annually at wholesale for municipal purposes.

(ii) "Water supplier" refers to both "urban water suppliers" and "agricultural water suppliers," but for purposes of section 5003, does not include agricultural water suppliers during the time that they may be exempted by section 10853 of the Water Code from the requirements of Parts 2.55 and 2.8 of Division 6 of the Water Code.

23 CCR Section 5001
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85057.5, 85059, 85058, 85066, 85020, 85054, 85052, 85302(g), 85308, 85300, 10608.12, and 10853, Water Code.

Key Terms, Acronyms, and Abbreviations Used in the Delta Plan

Term	Definition
100-year flood	A flood event having a 1-in-100 chance of being equaled or exceeded in any given year.
200-year flood	A flood event having a 1-in-200 chance of being equaled or exceeded in any given year.
AB	Assembly Bill
acre-foot	The volume of water that would cover 1 acre of land to a depth of 1 foot; equal to 43,560 cubic feet or 325,851 gallons.
accommodation space	The space in the Delta that lies below sea level and is filled with neither sediment nor water.
Act	See Sacramento-San Joaquin Delta Reform Act of 2009
ACWA	Association of California Water Agencies
administrative procedure	Procedures adopted by the Delta Stewardship Council (Council), in accordance with Water Code section 85225.30, that govern how the Council considers appeals with respect to the following: (1) Adequacy of certifications of consistency with the Delta Plan submitted to the Council by a State or local agency pursuant to Water Code section 85225.10, and (2) Determinations by the California Department of Fish and Wildlife that the Bay Delta Conservation Plan has met the requirements of Water Code section 85320 for inclusion in the Delta Plan.
advanced treatment	Any treatment of sewage that goes beyond the secondary or biological water treatment stage and includes the removal of nutrients, including phosphorus, nitrogen, and a high percentage of suspended solids.
Aeration Facility	Demonstration Dissolved Oxygen Aeration Facility
agricultural water use	Water used for farming, horticulture, or ranching including irrigation, stock watering, or support of vegetation for range grazing. This includes water used for irrigation and nonirrigation purposes. Irrigation water use includes the artificial application of water on land to promote the growth of crops and pasture, or to maintain vegetative growth in recreational lands, parks, and golf courses. Nonirrigation water use includes water used for livestock, which includes water for stock watering, feedlots, and dairy operations, and fish farming and other farm requirements.
agricultural water use efficiency	Defined by California Department of Water Resources as the ratio of applied water to the amount of water required to sustain agricultural productivity. Efficiency is increased through the application of less water to achieve the same beneficial productivity or by achieving more productivity while applying the same amount of water.
AGWA	Association of Groundwater Agencies
anadromous fish	Fish that are born in fresh water, migrate to the ocean to mature, and then return to fresh water to spawn.

Term	Definition
anticipated future stressors	Stressors that require preparation and planning for mitigation in advance of their onset (for example, future land subsidence, urban expansion, and new invasions by nonnative species).
artesian water	A groundwater aquifer under positive pressure. In some cases, the hydrostatic equilibrium elevation of the groundwater is higher than the elevation of the surrounding ground surface. When an artesian aquifer is penetrated by a well, the water level will rise above the top of the aquifer, and even flow out of the ground.
AWWA	American Water Works Association
BAFF	bio-acoustic fish fence
base camp	A park, resort, or town that provides services (for example, park rangers, interpretation, and boat rentals) and facilities (for example, parking, restrooms, picnic sites, boat ramps, and campgrounds). The mix of facilities is determined by adjacent recreation opportunities and nearby public and private facilities.
basin plan	A water quality control plan for a specific basin or region in California. It includes a comprehensive program of actions designed to preserve, enhance, and restore water quality in that basin. The basin plan is the master water quality control planning document for the regional boards. It describes beneficial uses of surface water and groundwater, and establishes water quality objectives to protect those uses.
Bay Plan	San Francisco Bay Plan
Bay-Delta Plan	Bay-Delta Water Quality Control Plan
BCDC	San Francisco Bay Conservation and Development Commission
BDCP	Bay Delta Conservation Plan
beneficial uses	Uses of the waters of the state that include domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves.
beneficiaries	Entities that benefit from using the resources of the Delta, including water supply, conveyance, and recreation.
benthic	The collection of organisms living on or in sea, lake, or river bottoms.
best management practices (BMPs)	Methods or techniques found to be the most effective and practical means of achieving an objective, such as water conservations. BMPs include, but are not limited to, structural and nonstructural controls, and operation and maintenance procedures. Examples of water conservation BMPs include tiered rate structures and water-efficient plumbing and irrigation systems.
bioaccumulation	The process by which a chemical is taken up by an aquatic organism, both from direct exposure to water and through the consumption of food containing the chemical.
biological opinion	A document stating the opinion of the U.S. Fish and Wildlife Service or the National Marine Fisheries Service as to whether or not federal action is likely to jeopardize the continued existence of a threatened or endangered species, or result in the destruction or adverse modification of critical habitat.

Term	Definition
biomagnify, biomagnification	The sequence of processes in an ecosystem by which higher concentrations of a particular chemical, a pesticide for example, are reached in organisms higher up the food chain, generally through a series of prey-predator relationships.
BMP	See best management practices
bypass	An area of land or a large, constructed structure designed to convey excess floodwaters from a river or stream in order to reduce the risk of flooding on the natural river or stream near a city or other population center.
Cal EMA	California Emergency Management Agency
Caltrans	California Department of Transportation
CARB	California Air Resources Board
carbon sequestration	The process of removing carbon from the atmosphere and storing it. Trees and plants, for example, absorb carbon dioxide, release the oxygen, and store the carbon in their biomass. The stored biomass may eventually turn to peat, other soil-borne organic matter, and fossil fuels such as coal or petroleum that will continue to store the carbon until the fuels are burned.
CASGEM	California Statewide Groundwater Elevation Monitoring Program
CCR	*California Code of Regulations*
CDFA	California Department of Food and Agriculture
centrarchids	Small, carnivorous, freshwater, spiny-finned fishes of North America usually having a laterally compressed body and metallic luster (for example, largemouth bass, smallmouth bass, spotted bass, bluegill, warmouth, redear sunfish, green sunfish, white crappie, and black crappie).
certification of consistency	The written certification to the Delta Stewardship Council, with detailed findings, that a covered action is consistent with the Delta Plan. Certifications of consistency are submitted to the Delta Stewardship Council by the State or local agency that is proposing to carry out, fund, or approve a covered action under the California Environmental Quality Act (Water Code section 85225 et seq.).
CEQA	California Environmental Quality Act
cfs	cubic feet per second
channelization	(1) Natural or intentional straightening and deepening of streams through dredging or construction of levees. (2) A marsh-drainage tactic that can disturb fish and wildlife habitats, aggravate flooding, and decrease the capacity to absorb pollution without suffering damage.
climate change	Any significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer). Climate change may result from (1) natural factors, including changes in the sun's intensity or changes in the Earth's orbit around the sun, (2) natural processes within the climate system (such as changes in ocean circulation), or (3) human activities that change the composition of the atmosphere (for example, through burning fossil fuels) and land surfaces (for example, deforestation, reforestation, urbanization, and desertification).

Term	Definition
CNDDB	California Natural Diversity Database
CNPS	California Native Plant Society
CNRA	California Natural Resources Agency
CO_2	carbon dioxide
COA	Coordinated Operating Agreement
conceptual model	An explicit description of mental models, knowledge, and hypotheses about the structure and function of a system or process.
conjunctive management	The coordinated and planned management of both surface water and groundwater resources to maximize efficient water use. Water is stored in groundwater basins for future use by intentionally recharging the basin during years of above-average surface water supply. Surface water and groundwater resources typically differ significantly in their availability, quality, management requirements, and development and use costs. Managing both resources together, rather than in isolation from one another, allows water managers to use the advantages of both resources for maximum benefit.
conveyance	The movement of water from one place to another. Conveyance infrastructure includes natural watercourses as well as canals, pipelines, and control structures including weirs. Examples of natural watercourses include streams, rivers, and groundwater aquifers. Conveyance facilities range in size from small, local, end-user distribution systems to large systems that deliver water to or drain areas covering multiple hydrologic regions. Conveyance facilities require associated infrastructure including pumping plants, power supply, diversion structures, fish ladders, and fish screens.
Council	Delta Stewardship Council
critical habitat	Specific areas, both occupied and unoccupied, that are essential to the conservation of a listed species and that may require special management considerations or protection (as defined in Section 3 of the federal Endangered Species Act).
current stressors	Stressors that result from ongoing human activities that can, in some cases, be eliminated (for example, fish entrainment at water diversions).
CVFPB	Central Valley Flood Protection Board
CVFPP	Central Valley Flood Protection Plan
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability Program
CWA	Clean Water Act
CZMA	Coastal Zone Management Act of 1972
DBW	California Department of Boating and Waterways
DDT	dichlorodiphenyltrichloroethane

Term	Definition
dedicated (or developed) water	Defined by California Department of Water Resources (DWR) as water distributed among urban and agricultural uses, used for protecting and restoring the environment, or storage in surface water and groundwater reservoirs. In any year, some of the dedicated supply includes water that is used multiple times (reuse) and water that is held in storage from previous years. DWR identifies California's average annual dedicated water supply as 85 million acre-feet. *See also: total water use.*
Delta	Sacramento-San Joaquin Delta
Delta Conservancy	Sacramento–San Joaquin Delta Conservancy
Delta Ecological Management Zone	The Delta conservation strategy adopted by the Department of Fish and Wildlife as the *Ecosystem Restoration Program Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions.*
Delta exports	Describes, in general terms, any water diverted from the Delta for use outside the Delta, including water pumped by the State Water Project and Central Valley Project pumping plants, Contra Costa Water District, and other agencies. The term must be precisely defined when applied to specific studies or analyses.
Delta Flood Risk Management Assessment District	As proposed in the Delta Plan, an assessment district authorized to set fees on State and local infrastructure to generate funds for levee maintenance and surveys; adequate flood control protection; and emergency response for the benefit of landowners, infrastructure owners, and other entities that benefit from the maintenance and improvement of Delta levees, including water users who rely on the levees to protect water quality.
Delta Independent Science Board (Delta ISB)	Established by the Sacramento-San Joaquin Delta Reform Act of 2009, the Delta ISB is a standing board of nationally and internationally prominent scientists with appropriate expertise to evaluate the broad range of scientific programs that support adaptive management of the Delta. The Delta ISB will provide oversight of the scientific research, and monitoring and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs. The overall objective of Delta ISB oversight is to help make the science underlying Bay-Delta programs, the application of that science, and the technical aspects of those programs the best they can be (Water Code section 85280 et seq.).
Delta ISB	See Delta Independent Science Board
Delta Levee Special Flood Control Projects	A California Department of Water Resources program, authorized in Water Code sections 12300 through 12314, that provides financial assistance to local levee-maintaining agencies for rehabilitating levees in the Delta.
Delta Multi-Hazard Coordination Task Force	A task force established to address emergency preparedness and response issues in the Delta by enabling the development and implementation of multi-hazard preparedness and response strategies for the Delta. Led by the California Emergency Management Agency (Cal EMA), the task force consisted of representatives from the Delta Protection Commission, California Department of Water Resources, and representatives of the five Delta counties. The passage of Senate Bill 27 in 2008 required Cal EMA, formerly the Office of Emergency Services, to establish the task force.

Term	Definition
Delta Primary Zone	The Sacramento-San Joaquin River Delta land and water area of primary State concern and statewide significance that does not encompass either the urban limit line or sphere of influence line of any local government general plan or study existing as of January 1, 1992. The precise boundary lines of the Primary Zone include the land and water areas as shown on the map titled "Delta Protection Zones" on file with the California State Lands Commission. Where the boundary between the Primary Zone and Secondary Zone is a river, stream, channel, or waterway, the boundary line is the middle of that river, stream, channel, or waterway. The Primary Zone consists of approximately 500,000 acres (Public Resources Code section 29728).
Delta Reform Act	See Sacramento-San Joaquin Delta Reform Act of 2009
Delta Secondary Zone	All the Delta land and water area within the boundaries of the Delta not included within the Primary Zone, subject to the land use authority of local government, and that includes the land and water areas as shown on the map titled "Delta Protection Zones" on file with the State Lands Commission. The Secondary Zone consists of approximately 238,000 acres (Public Resources Code section 29731).
Delta Vision	Delta Vision Blue Ribbon Task Force
Delta watershed	The watershed of the Sacramento River Hydrologic Region and the San Joaquin River Hydrologic Region as described in the California Water Plan Update 2005, Bulletin 160-05 (Water Code section 85060).
demand management measures	Water conservation measures, programs, and incentives that prevent the waste of water and promote the reasonable use and reuse of available supplies.
desalination	A water treatment process for the removal of salt from water for beneficial use. Source water can be brackish (low salinity) or sea water.
DFG	California Department of Fish and Game
DFW	California Department of Fish and Wildlife (formerly the California Department of Fish and Game)
diversion	A process which, having return flow and consumptive use elements, turns water from a given path. Removal of water from its natural channel for human use. Use of part of a streamflow as a water supply. Channel constructed across the slope for the purpose of intercepting surface runoff, changing the accustomed course of all or part of a stream. A structural conveyance (or ditch) constructed across a slope to intercept runoff flowing down a hillside and divert it to some convenient discharge point.
DO	dissolved oxygen
DOC	California Department of Conservation
DPC	Delta Protection Commission
DPH	California Department of Public Health
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
drinking water quality	Drinking water quality standards are adopted by the California Department of Public Health (DPH) Drinking Water Program pursuant to the California Safe Drinking Water Act. The standards apply to public drinking water systems and to water delivered to customers, and are enforceable by DPH and local health departments.

Term	Definition
drought	Hydrologic conditions during a defined period, greater than 1 dry year, when precipitation and runoff are much less than average.
DWR	California Department of Water Resources
DWR 200 Year	DWR 200-year Urban Levee Protection
EAD	See expected annual damage
ecosystem	A biotic community and its physical environment, considered as an integrated unit. Implied within this definition is the concept of a structural and functional whole unified through life processes. An ecosystem may be characterized as a viable unit of community and interactive habitat. Ecosystems are hierarchical and can be viewed as nested sets of open systems in which physical, chemical, and biological processes form interactive subsystems. Some ecosystems are microscopic, and the largest comprises the biosphere. Ecosystem restoration can be directed at different-sized ecosystems within the nested set, and many encompass multiple states, more localized watersheds, or a smaller complex of aquatic habitat.
ecosystem enhancement	The improvement of existing desirable habitat and natural processes. Enhancement might include flooding the Yolo Bypass more often, at times, to support native species, or expand or better connect existing habitat areas. Enhancement also includes many fish and wildlife management practices, including managing wetlands for waterfowl production or shorebird habitat, installing fish screens to reduce entrainment of fish at water diversions, or removing barriers that block migration of fish to upstream spawning habitats.
ecosystem protection	Preventing harm to an ecosystem, which could include preventing the conversion of existing habitat, the degradation of water quality, irretrievable conversion of lands suitable for restoration, or the spread of invasive nonnative species.
ecosystem restoration	The application of ecological principles to restore a degraded or fragmented ecosystem and return it to a condition in which its biological and structural components achieve a close approximation of its natural potential, taking into consideration the physical changes that have occurred in the past and the future impact of climate change and sea level rise (Water Code section 85066).
Ecosystem Restoration Program Conservation Strategy	Describes the Ecosystem Restoration Program (ERP) priorities and actions for Stage 2 of the CALFED Bay-Delta Program (summarized in Appendix B). It identifies biologically promising ecosystem restoration opportunities in the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento Valley and San Joaquin Valley regions, and it provides the rationale for restoration actions specific to each of these regions. It further provides the conceptual framework and process to guide the refinement, evaluation, prioritization, implementation, monitoring, and review of ERP actions.
ecosystem water quality	The Delta ecosystem is affected by a variety of pollutants discharged into Delta and tributary waters. Pollutants of concern affecting Delta biological species and ecosystem processes include nutrients, pesticides, mercury, selenium, and other persistent bioaccumulative toxic substances. Newly identified pollutants of potential concern (often referred to as emerging contaminants) also should be investigated.
EIR	environmental impact report

Term	Definition
endangered species	As defined by the California Endangered Species Act, an endangered species is a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant that is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease. Any species determined by the Fish and Game Commission as endangered on or before January 1, 1985, is an endangered species (Fish and Game Code section 2062).
entrainment	Defined by the National Marine Fisheries Service as "the incidental trapping of any life stage of fish within waterways or structures that carry water being diverted for anthropogenic use."
environmental water	Minimum flow levels of a specific quality that are needed in order to assure the continued viability of fish and wildlife resources for a particular water body. This water is used to maintain and enhance the beneficial uses related to the preservation and enhancement of fish, wildlife, and other aquatic resources or preserves as specified in the Porter-Cologne Water Quality Control Act.
environmental water use	Water dedicated to instream environmental needs.
EPRRP	Emergency Preparedness Response and Recovery Program
ERP	Ecosystem Restoration Program
ESA	Endangered Species Act
ESP	The Delta Protection Commission's *Economic Sustainability Plan for the Sacramento-San Joaquin Delta*
estuary	A place where fresh and salt water mix, such as a bay, salt marsh, or where a river enters an ocean.
expanded water supply reliability element	Additional information water suppliers should include in their water supply reliability element, starting in 2015, as part of the update of any urban water management plan, agricultural water management plan, integrated water management plan, or other plan that provides equivalent information on the supplier's planned investments in water conservation and water supply development. This expanded water supply reliability element must detail how water suppliers are improving regional self-reliance and reducing reliance on the Delta through investments in local and regional programs and projects, and must document actual and projected reductions in reliance on Delta exports. At a minimum, the water reliability element must include the following: (1) A plan for possible interruption of Delta water supply due to catastrophic events. (2) A plan for implementation of anticipated investments in water conservation, water efficiency, and water supply development. (3) Evaluation of regional water balance. (4) Conservation-oriented water rate structure.
expected annual damage (EAD)	A metric for analyzing flood risk that integrates the likelihood and consequences of flooding. Generally defined as the average annual flood damages (in dollars) weighted by the probability that a flood will occur in any given year. The U.S. Army Corps of Engineers describes EAD mathematically in *Manual No. 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies*, August 1, 1996.
FEMA	Federal Emergency Management Agency
FEMA 100 Year	FEMA 100-year (Base Flood) Protection

Term	Definition
flood risk	The likelihood and consequence of inundation by floodwaters. Consequences may include direct or indirect economic costs, loss of life, environmental impacts, or other specified measures of flood effect. Flood risk is a function of (1) loading, which is the frequency and magnitude of flood discharge or stage; (2) limits to exposure to the loading due to flood defense measures; and (3) consequence. Therefore, flood management actions may reduce risk by changing loading, exposure, or consequence. For clarity, flood risk is commonly quantified within an identified area for a specified climate condition, land use condition, and with a flood management system (existing or planned) in place.
flow criteria	The development of specific criteria by the State Water Resources Control Board for flows for the Delta ecosystem, including the volume, quality, and timing of water necessary for the Delta ecosystem under different conditions (Water Code section 85086(c)(1)).
flow objectives	Where protection of beneficial uses requires specific flow volumes at certain times, regional water quality control boards may establish flow objectives in water quality control plans. They differ from typical water quality objectives in that they are implemented by the State Water Resources Control Board through modifications and limitations of existing or future water rights to make sure these flows are met.
flow regime	The regulation of ecological processes in river ecosystems: the magnitude, frequency, duration, timing, and rate of change of hydrologic conditions (Poff and Ward 1989, Richter et al. 1996, Walker 1995). These components can be used to characterize the entire range of flows and specific hydrologic phenomena, including floods or low flows, that are critical to the integrity of river ecosystems. Furthermore, by defining flow regimes in these terms, the ecological consequences of particular human activities that modify one or more components of the flow regime can be considered explicitly.
flow requirements	The amount of water required for instream use by agreement, water rights permit, or State/federal law.
freeboard	The height of the physical top of a levee or floodwall above the median design water surface elevation.
gateway	A community, landmark, or signage on the edge of the Delta or Suisun Marsh that serves as a gateway providing information to visitors about recreation opportunities available in the area and equipping them with supplies.
general obligation bond	A bond issued by the State where the principal and interest is paid out of the General Fund. This is different than a revenue bond, where the principal and interest is paid out of a specific dedicated revenue source.
globally determined stressors	Stressors that result from large-scale human activities or natural processes that cannot be eliminated or mitigated within a limited purview and require larger-scale planning and adaptation (such as global climate change and human population growth).
GPCD	gallons per capita daily
groundwater basin	An alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom.
groundwater management plan	A comprehensive written document developed for the purpose of groundwater management and adopted by an agency having appropriate legal or statutory authority.

Term	Definition
groundwater overdraft	The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds the amount of water that recharges the basin over a period of years during which water supply conditions approximate average conditions.
groundwater remediation	The extraction of contaminated groundwater from an aquifer followed by treatment and (1) replacement in the aquifer or (2) use for agricultural or municipal purposes.
groundwater storage	Defined three ways depending on the context: (1) the quantity of water beneath the land surface that fills the pore spaces of the alluvium, soil, or rock formation; (2) the volume of usable physical space available to store water in the pore spaces of the alluvium, soil, or rock formation beneath the land surface; or (3) the act of storing water in the pore spaces of the alluvium, soil, or rock formation beneath the land surface.
HAB	harmful algal bloom
habitat	The location and the living and nonliving surroundings where a particular plant or animal lives. Habitat includes the presence of a group of particular environmental conditions surrounding an organism including air, water, soil, mineral elements, moisture, temperature, and topography.
Habitat Conservation Plan (HCP)	A plan prepared under the Endangered Species Act by nonfederal parties in order to obtain permits for incidental taking of threatened and endangered species. The HCP describes ways to maintain, enhance, and protect a given habitat type needed to protect species. The plan usually includes measures to minimize impacts, and might include provisions for permanently protecting land, restoring habitat, and relocating plants or animals to another area.
habitat restoration	The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning the majority of natural functions to the lost or degraded native habitat.
Hazard Mitigation Plan (HMP)	Refers to levee guidance negotiated between various federal, State, and local agencies to assist in reducing the likelihood of repetitive flood damage to Delta levees and islands. This guidance provides geometric levee design criteria that, if maintained, make a Delta levee-maintaining agency eligible for federal disaster assistance funds in the event of a flood emergency.
HCP	See Habitat Conservation Plan
HGMP	Hatchery and Genetic Management Plans
HMP	See Hazard Mitigation Plan
hydraulic mining	The use of high-pressure jets of water to dislodge rock material or move sediment.
hydrodynamics	The description of the change in flow or motion of a liquid.
hydrologic region	A geographical division of the state based on local hydrologic basins. The California Department of Water Resources divides California into 10 hydrologic regions, corresponding to the state’s major water drainage basins: North Coast, San Francisco Bay, Central Coast, South Coast, Sacramento River, San Joaquin River, Tulare Lake, North Lahontan, South Lahontan, and Colorado River.
IEP	Interagency Ecological Program
incidental take permit	A permit issued by federal fisheries agencies that authorizes take of listed species incidental to otherwise lawful projects.

Term	Definition
instream flow	The use of water within its natural watercourse as specified in a contract, a water rights permit, a court order, a Federal Energy Regulatory Commission license, or other documentation. Instream flows support natural ecosystems, create habitat for plants and animals, and may provide additional benefits including recreation. *See also: flow requirements*.
integrated regional water management	A collaborative effort to manage all aspects of water resources in a specified region. Integrated regional water management crosses jurisdictional, watershed, and political boundaries; involves multiple agencies, stakeholders, individuals, and groups; and attempts to address the issues and differing perspectives of all entities involved through mutually beneficial solutions.
integrated regional water management plan (IRWMP)	At a minimum, an integrated regional water management plan describes the major water-related objectives and conflicts within a region; considers a broad variety of water management strategies; identifies an appropriate mix of water demand and supply management alternatives; provides water quality protections and environmental stewardship actions to provide a long-term, reliable, and high-quality water supply; protects the environment; and identifies disadvantaged communities in the region taking into account the water-related requirements of those communities.
invasive species	An alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health (Executive Order 13112, 1999).
land reclamation	The process to recover land through channelization and levee construction of what was previously marsh land.
IRWMP	See integrated regional water management plan.
LADWP	Los Angeles Department of Water and Power
LAEDC	Los Angeles Economic Development Corporation
LAO	California Legislative Analyst's Office
legacy community	A rural community registered as a Historic District by either a State or federal entity. Delta legacy communities include Bethel Island, Clarksburg, Courtland, Freeport, Hood, Isleton, Knightsen, Rio Vista, Ryde, Locke, and Walnut Grove (Public Resources Code section 32301(f)).
legacy stressors	Stressors that result from past actions that cannot be undone, but whose impact can sometimes be reduced or mitigated (for example, mercury pollution from historical gold mining).
Legislature	California Legislature
levee-maintaining agencies	Local special districts, typically reclamation districts, that are public agencies formed for the purpose of levee maintenance and improvement, among other duties, and are funded by local assessments.
levee standards	Standards designed to either establish minimum criteria that would make levees and the properties protected eligible for Federal Emergency Management Agency (FEMA) grants or U.S. Army Corps of Engineers (USACE) rehabilitation funds both in case of catastrophic emergency, or set minimum criteria that would allow development behind the levees. The four main applicable levee standards and guidance for the Delta are (1) FEMA Hazard Mitigation Plan Guidance, (2) USACE Public Law 84-99, (3) FEMA 100-year (Base Flood) Protection, and (4) DWR 200-year Urban Levee Protection.
LHC	Little Hoover Commission

Term	Definition
low salinity zone (LSZ)	Generally, the region in an estuary with salinity ranging from fresh water up to about 5 parts per thousand (ppt), about one-seventh the salinity of sea water. The part of the salinity gradient centered on 2 ppt is considered to be of particular importance because it is hypothesized to be an area where suspended particulate matter and organisms accumulate. The location in the Bay-Delta where the tidally averaged salinity at 1 meter from the bottom is 2 ppt is known as X2 (measured as distance in kilometers from the Golden Gate Bridge) and serves as a water quality objective regulating Delta outflow.
LPP	Suisun Marsh Local Protection Program
LSZ	See low salinity zone
LTMS	Delta Dredged Sediment Long-Term Management Strategy
µS/cm	microsiemens per centimeter
MAF	million acre-feet
managed wetland	Perched wetlands that receive human-induced seasonal flooding for marshland development.
MCL	maximum contaminant level
mg/L	milligram(s) per liter
MWD	Metropolitan Water District of Southern California
NAS	National Academy of Sciences
National Heritage Area (NHA)	Places designated by the United States Congress where natural, cultural, historic, and recreational resources combine to form a cohesive, nationally distinctive landscape arising from patterns of human activity shaped by geography. These areas tell important stories about the nation and are representative of the national experience through both the physical features that remain and the traditions that have evolved within them.
National Pollutant Discharge Elimination System (NPDES)	A permitting program required for all point sources discharging pollutants into waters of the United States. The purpose of the NPDES program is to protect human health and the environment (Clean Water Act of 1977, 33 United States Code section 1311).
Natural Community Conservation Plan (NCCP)	A conservation plan created to meet the requirements of the Natural Community Conservation Planning Act, which identifies and provides for the regional or areawide protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity. The primary objective of the NCCP program is to conserve natural communities at the ecosystem level while accommodating compatible land use (Fish and Game Code section 2800 et seq.).
NCCP	See Natural Community Conservation Plan
new water	Defined in part by California Department of Water Resources as water that is legally and empirically available for a beneficial use. New water can be developed through many strategies such as capturing surplus water, desalinating ocean water, and improving water efficiency.
NHA	See National Heritage Area
NMFS	National Marine Fisheries Service

Term	Definition
nonpoint source pollution	Diffused sources that do not have a single point of origin or are not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater runoff. Common categories of nonpoint sources are agriculture, forestry, mining, construction, land disposal, and salt intrusion.
NPDES	See National Pollutant Discharge Elimination System
NRC	National Research Council
NWR	National Wildlife Refuge
OP	organophosphorus
OPC	California Ocean Protection Council
Paterno v. State of California	In *Paterno v. State of California*, the appellate court found the State liable for flood-related damages caused by the failure of a Yuba River levee incorporated into the State system of flood control, even though the State did not design, build, or even directly maintain it (*Paterno v. State* [2003] 113 Cal. App.4th 998 [6 Cal.Rptr.3d 854]).
PCB	polychlorinated biphenyl
peak flow	Maximum instantaneous flow in a specified period.
pelagic fish	A fish species that spends most of its life swimming in the water column with little contact with or dependency on the bottom. Adult spawning usually occurs in open water, often near the surface.
pelagic organism decline (POD)	A steep decline leading to near-record low populations of four pelagic species in the San Francisco Estuary—delta smelt, young striped bass, longfin smelt, and threadfin shad—widely recognized as a serious issue by 2004.
performance measures	A quantitative or qualitative tool to assess progress toward an outcome or goal. The Delta Plan must include performance measurements that will enable the Delta Stewardship Council to track progress in meeting the objectives of the Plan. Performance measurements must include, but need not be limited to, quantitative or otherwise measurable assessments of the status and trends in all of the following: (1) The health of the Delta estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes including viable populations of Delta fisheries and other aquatic organisms. (2) The reliability of California water supply imported from the Sacramento River or the San Joaquin River watershed.
PL 84-99	See Public Law 84-99
Plan	Delta Plan
POD	See pelagic organism decline

Term	Definition
point source	Any discernible, confined, and discrete conveyance including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, landfill leachate collection system, vessel, or other floating craft from which pollutants are or may be discharged. This term does not include return flows from irrigation agriculture or agricultural stormwater runoff (40 *Code of Federal Regulations* 122.2).
pollutant	Defined as "dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water" (Clean Water Act of 1977, 33 United States Code section 1362(6)).
pollution	Defined as the human-made or human-induced alteration of the chemical, physical, biological, and radiological integrity of water (Clean Water Act section 502(19); 33 United States Code section 1362(19)). Pollution is also defined in California law as an alternation of the quality of the waters of the state by waste to a degree that unreasonably affects either the waters for beneficial uses or the facilities that serve these beneficial uses (Water Code section 13050(k)(1)).
ppb	parts per billion
PPIC	Public Policy Institute of California
ppm	parts per million
ppt	parts per thousand
PRBO CalPIF	Point Reyes Bird Observatory California Partners in Flight
Public Law 84-99 (PL 84-99)	A federal levee standard developed by the U.S. Army Corps of Engineers (USACE). Meeting this standard allows the Delta island or tract to be eligible for USACE funding for levee rehabilitation, island restoration after levee failures, and island inundation, provided that the reclamation district applies for and is accepted into the USACE's Rehabilitation and Inspection Program.
Public Trust Doctrine	This doctrine protects the right of the public to use State sovereign lands and waters for commerce, navigation, hunting, fishing, bathing, swimming, boating, and general recreational purposes, and also protects trust lands and waters in their natural state, so that they may serve as ecological units for scientific study, as open space, and as environments that provide food and habitat for birds and marine life, and which favorably affect the scenery and climate of the area. There is also a separate branch of the Public Trust Doctrine that protects the fishery resources in all State waters, including those in nonnavigable waterways, as public trust resources in and of themselves.

Term	Definition
Reasonable and Beneficial Use Doctrine	This doctrine states that a water right does not include the right to waste water and mandates that the water resources of the state be put to beneficial use. "It is hereby declared that because of the conditions prevailing in this State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare. The right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water. Riparian rights in a stream or water course attach to, but to no more than so much of the flow thereof as may be required or used consistently with this section, for the purposes for which such lands are, or may be made adaptable, in view of such reasonable and beneficial uses; provided, however, that nothing herein contained shall be construed as depriving any riparian owner of the reasonable use of water of the stream to which the owner's land is riparian under reasonable methods of diversion and use, or as depriving any appropriator of water to which the appropriator is lawfully entitled. This section shall be self-executing, and the Legislature may also enact laws in the furtherance of the policy in this section contained" (California Constitution Article X section 2).
reasonable and prudent alternative	The regulations implementing Section 7 of the Endangered Species Act define reasonable and prudent alternatives as alternative actions, identified during formal consultation, that (1) can be implemented in a manner consistent with the intended purpose of the action, (2) can be implemented consistent with the scope of the action agency's legal authority, (3) are economically and technologically feasible, and (4) would, according to the National Marine Fisheries Service, avoid the likelihood of jeopardizing the continued existence of listed species and avert the destruction or adverse modification of critical habitat (Endangered Species Act of 1973, 16 United States Code section 1536).
Reclamation	Bureau of Reclamation
Recreation Proposal	*Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh*
regional self-reliance	The degree to which a region implements water management options so that it can provide for all of its needs for water from within its own borders.
regional water supplies	Water supplies that are found or developed within a region to be used within its own borders.
reservoir reoperation	Changes to existing operations and management procedures for existing reservoirs and conveyance facilities to increase water-related benefits from these facilities.
resource management strategy	A project, program, or policy that helps federal, State, or local agencies manage water and related resources. Resource management strategies in the California Water Plan are grouped by intended outcomes: reduce water demand, improve operational efficiency and transfers, increase water supply, improve water quality, practice resource stewardship, and improve flood management. Although most of the resource management strategies have multiple potential benefits, any individual site-specific project or program within a resource management strategy may contribute only one, or a few, of the benefits.
riparian area	The land adjacent to a natural watercourse such as a river or a stream. Riparian areas support vegetation that provides important wildlife habitat and important fish habitat when shading the watercourse bank.

Term	Definition
RWCF	Stockton Regional Wastewater Control Facility
RWQCB	Regional Water Quality Control Board
SACOG	Sacramento Area Council of Governments
Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act or Act)	Included in Senate Bill X71, established a new governance approach for the Sacramento-San Joaquin Delta that is focused on achieving the coequal goals and is fundamentally different from past approaches. The Delta Reform Act created the Delta Stewardship Council and gave it the direction and authority to serve two primary governance roles: (1) set a comprehensive, legally enforceable direction for how the State manages important water and environmental resources in the Delta through the adoption of a Delta Plan, and (2) ensure coherent and integrated implementation of that direction through coordination and oversight of State and local agencies proposing to fund, carry out, and approve Delta-related activities.
Safe Harbor Agreement	A voluntary agreement made between wildlife agencies and landowners in order to recover a listed species.
SAV	submerged aquatic vegetation
SB	Senate Bill
SBX7 1	Senate Bill X7 1
SBX7 7	Senate Bill X7 7
SDWSC	Stockton Deep Water Ship Channel
sea level rise	A change in average global sea level caused by a change in ocean volume. Often discussed in relation to climate change.
seepage	Percolation of water through the soil from unlined canals, ditches, laterals, watercourses, or water storage facilities.
SEMS	See Standardized Emergency Management System
sensitive species	Species not yet officially listed but undergoing status review for listing on the U.S. Fish and Wildlife Service's official threatened and endangered list; species whose populations are small and widely dispersed or restricted to a few localities; and species whose numbers are declining so rapidly that official listing may be necessary.
SFD	San Felipe Division
SHP	State Historic Park
SMPP	BCDC's *Suisun Marsh Protection Plan*
SOI	sphere of influence

Term	Definition
special-status species	Any species that is listed, or proposed for listing, as threatened or endangered by the U.S. Fish and Wildlife Service or National Marine Fisheries Service under the provisions of the Endangered Species Act; any species designated by the U.S. Fish and Wildlife Service as a "listed," "candidate," "sensitive," or "species of concern"; and any species listed by the State in a category implying potential danger of extinction.
SP	State Park
SPFC	State Plan of Flood Control
SRA	State Recreation Area
Standardized Emergency Management System (SEMS)	Established throughout California to manage and coordinate any emergency response involving more than one agency or jurisdiction. It is the cornerstone of the emergency response system and the fundamental structure for the response phase of emergency management. SEMS is authorized under the California Emergency Services Act for managing multiagency and multijurisdictional responses to emergencies in California.
State	State of California
stormwater capture system	A facility operated by a public agency and designed to capture and retain stormwater flowing upon the public right-of-way, or through a public stormwater management system or a public stormwater drainage system, for subsequent use.
stressors (ecosystem)	Actions or factors, whether human or natural, that cause negative impacts on desirable ecosystem elements, processes, and functions. *See also: globally determined stressor, legacy stressors, current stressors, and anticipated future stressors.*
stressor fees	A companion principle to user fee, stressor fees are paid by persons who have been identified as stressing Delta natural systems. The fees fund regulatory and restoration programs.
subsidence	Sinking of the land surface due to a number of factors, including groundwater extraction, agricultural activities, or oil or gas extraction. In the Delta, land subsidence is mainly caused by oxidation of peat soils, but also from wind erosion. Drainage and cultivation dries the saturated peat, reducing its volume by approximately 50 percent.
subsidence reversal	The exposure of bare peat soils to air causes oxidation and decomposition, which results in subsidence, or a loss of soil elevation, on Delta islands. Flooding these lands and managing them as wetlands reduces exposure to oxygen, resulting in less decomposition of organic matter, which stabilizes land elevations. Wetland vegetation cycles lead to biomass accumulation, which sequesters carbon and helps stop and reverse subsidence. As subsidence is reversed, land elevations increase and accommodation space (the space in the Delta that lies below sea level and is filled with neither sediment nor water) on individual islands is reduced. A reduction in accommodation space decreases the potential for water quality impacts from salinity intrusion in the event of one or more levee breaks on deeply subsided Delta islands.

Term	Definition
subventions	Payments made by the State in the form of matching funds for the purpose of maintaining and improving Delta levees. The Delta Levees Maintenance Subventions Program is a cost share program providing technical and financial assistance to local levee-maintaining agencies in the Sacramento–San Joaquin Delta for the maintenance and rehabilitation of nonproject and eligible project levees. The subventions program is authorized by Water Code sections 12980 through 12995 and is managed by the California Department of Water Resources.
surface storage	Reservoirs used to collect and hold water for future release and use.
surface water	Water naturally open to the atmosphere including rivers, lakes, reservoirs, ponds, streams, impoundments, seas, and estuaries.
sustainable communities strategy	Regional transportation agencies are required to develop a sustainable communities strategy. The strategy is intended to demonstrate how the region will meet its greenhouse gas reduction target through integrated land use, housing, and transportation planning.
SWP	State Water Project
SWRCB	State Water Resources Control Board
threatened species	As defined by the California Endangered Species Act, a threatened species is a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by the act. Any animal determined to be rare on or before January 1, 1985, is a threatened species (Fish and Game Code section 2067).
THM	trihalomethanes
tiered fee structures	Refers to a block-type fee structure where the unit price of a quantified benefit or impact, such as the amount of water used or the volume of contaminants discharged, increases with each additional block of benefit or impact.
TMDL	See total maximum daily load
total maximum daily load (TMDL)	A calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards.
total water use	In the Delta Plan, refers to 60 to 65 million acre-feet of water in California that goes to urban, agricultural, and Central Valley environmental water uses such as instream flow requirements and non-CVP managed wetlands.
tributary	A river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.
unimpaired flow	The natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds.
urbanization	The expansion of residential, commercial, and industrial development into rural areas or areas that may have previously been used for agricultural or ecosystem habitat.
urban water use	The use of potable and nonpotable water for urban purposes including, but not limited to, residential, commercial, industrial, recreation, energy production, military, and institutional purposes.

Term	Definition
urban water use efficiency	Water management measures that are implemented in residential, commercial, industrial, and institutional settings that reduce water and per capita water use and result in the most effective use of water to prevent its waste, unreasonable use, or unreasonable method of use.
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
user fees	Fees proposed to fund programs identified in the Delta Plan that are paid by the users or beneficiaries of those programs. Fees may be volume-based or impact-based.
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWMP	See urban water management plan
vector-borne disease	Disease that results from an infection transmitted to humans and other animals by blood-feeding anthropods, including mosquitoes, ticks, and fleas. Examples of vector-borne diseases include Dengue fever, viral encephalitis, Lyme disease, and malaria.
waste discharge requirement (WDR)	An order adopted by a regional water board that regulates and permits specified discharges of waste to surface water and discharges of waste to land.
water balance	An analysis of the total developed/dedicated supplies, uses, and operational characteristics of water in a region. The analysis is intended to determine if actual water use equals supply.
water demand	An economic principle that describes consumer desire and willingness to pay a price for a specific amount of water. Holding all other factors constant, the price of a good or service increases as its demand increases and vice versa.
water export	The amount of water that a hydrologic region transfers to another hydrologic region. *See also: Delta exports.*
water import	The amount of water brought in from another hydrologic region or regions.
water quality criteria	Numeric limitations or levels (for example, concentrations) or narrative statements established to protect uses of a water body under the authority of the Clean Water Act. This term has two separate meanings: (1) Water quality criteria promulgated by the U.S. Environmental Protection Agency under Clean Water Act section 303(c) are enforceable components of water quality standards. (2) Recommended water quality criteria published under Clean Water Act section 304(a) are advisory and may be used by states and tribes to develop their own water quality standards or to implement narrative criteria in water quality standards.
water quality objectives	Numeric limitations or levels (concentrations or narrative statements) that are established for the reasonable protection of the beneficial uses of a water body. Determination of what is reasonable may include factors that are not required in federal development of a water quality criterion. Water quality objectives are included in water quality control plans adopted by regional water boards.

Term	Definition
water quality standards	Pursuant to the federal Clean Water Act, water quality standards are provisions of State or federal law that define the water quality goals of a water body, or portion thereof, by establishing (a) designated uses of water to be protected, and (b) water quality criteria to protect those uses. Water quality standards are enforceable in the bodies of water for which they have been promulgated.
water recycling	(1) The treatment of wastewater to remove solids and certain impurities to meet a beneficial use or a controlled use that would not otherwise occur, thus supplanting or augmenting a potable, or potentially potable, supply. (2) The treatment of municipal, industrial, or agricultural wastewater for reuse.
watershed	The land area that drains into a stream. The watershed for a major river may encompass a number of smaller watersheds.
water shortage contingency element	The Urban Water Management Planning Act requires water suppliers to include a water supply reliability and water shortage contingency element in urban water management plans, recognizing that suppliers need to prepare for extended droughts or the potential catastrophic interruption of water deliveries due to earthquakes or other events.
water supply reliability	See sidebar in Chapter 3, "What Does It Mean to Achieve the Goal of Providing a More Reliable Water Supply for California?"
water supply reliability element	Required components of urban water management plans (Water Code section 10631(c)), agricultural water management plans (Water Code section 10826 (b)(7)), and integrated regional water management plans (Water Code section 10540(c)(1)).
water transfer	A temporary or long-term change in the point of diversion, place of use, or purpose of use due to a transfer or exchange of water or water rights. Many transfers, including transfers among contractors of the State Water Project or Central Valley Project, do not fit this definition. A more general definition of a water transfer is a voluntary change in the way water is normally distributed among water users in response to water scarcity. Compared to water exchanges, which are typically water delivered by one water user to another water user, the receiving water user will return the water at a specified time or when the conditions of the agreement are met (Water Code section 1735).
water year	A compilation of hydrologic records collected over a 12-month period.
water year-type classifications	California Department of Water Resources uses five water year-type classifications for planning and water management purposes: wet, above normal, below normal, dry, and critically dry.
WDR	See waste discharge requirement
Wild and Scenic River	A State- and federal-designated river system that includes 17 California rivers and their many forks and tributaries. Approximately 1,900 miles of river are designated wild, scenic, or recreational under the National Wild and Scenic Rivers Act (1968) and the California Wild and Scenic Rivers Act of 1972.
X2	The location in the Bay-Delta where the tidally averaged salinity is 2 parts per thousand.

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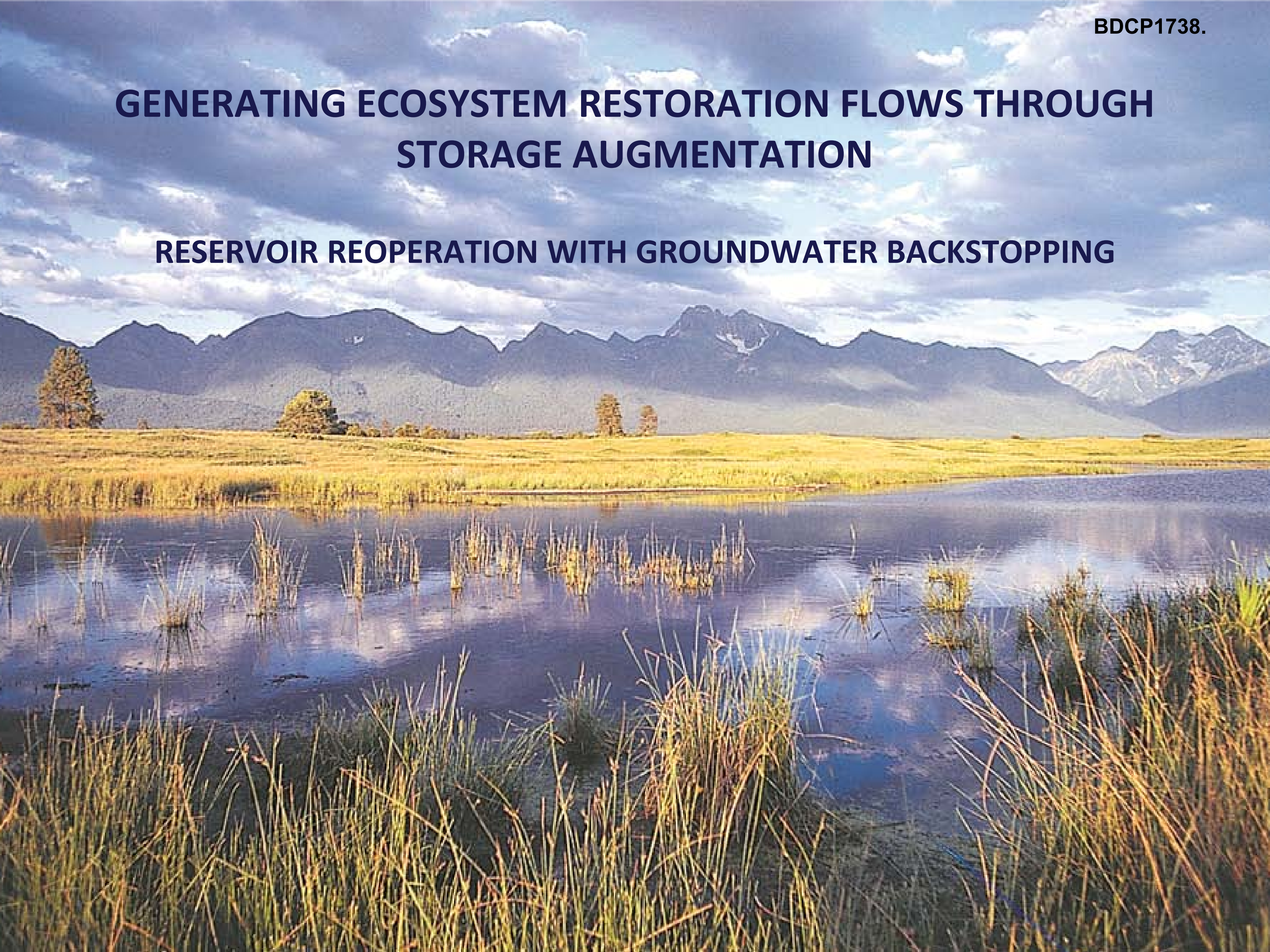
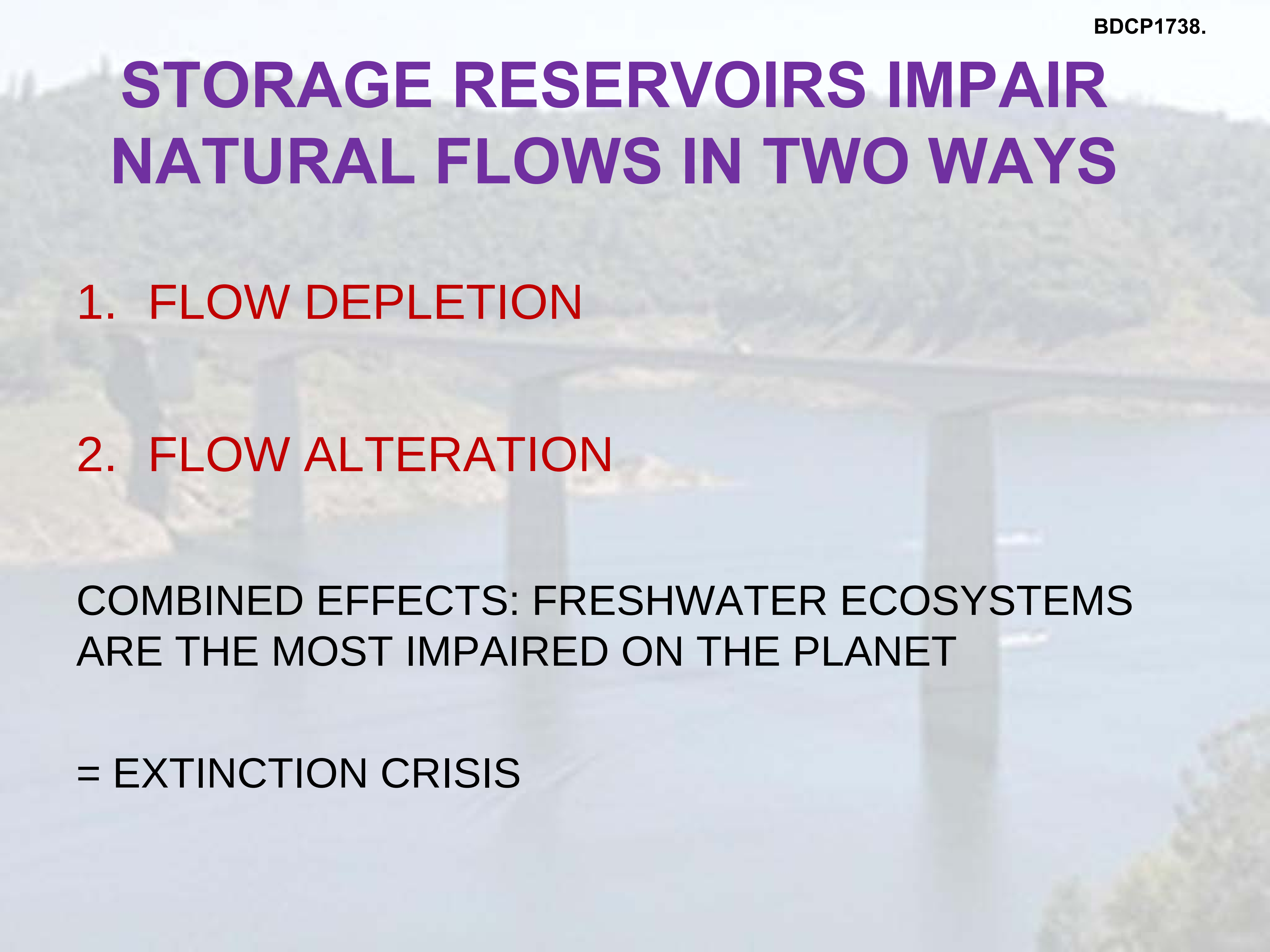


GENERATING ECOSYSTEM RESTORATION FLOWS THROUGH STORAGE AUGMENTATION

RESERVOIR REOPERATION WITH GROUNDWATER BACKSTOPPING

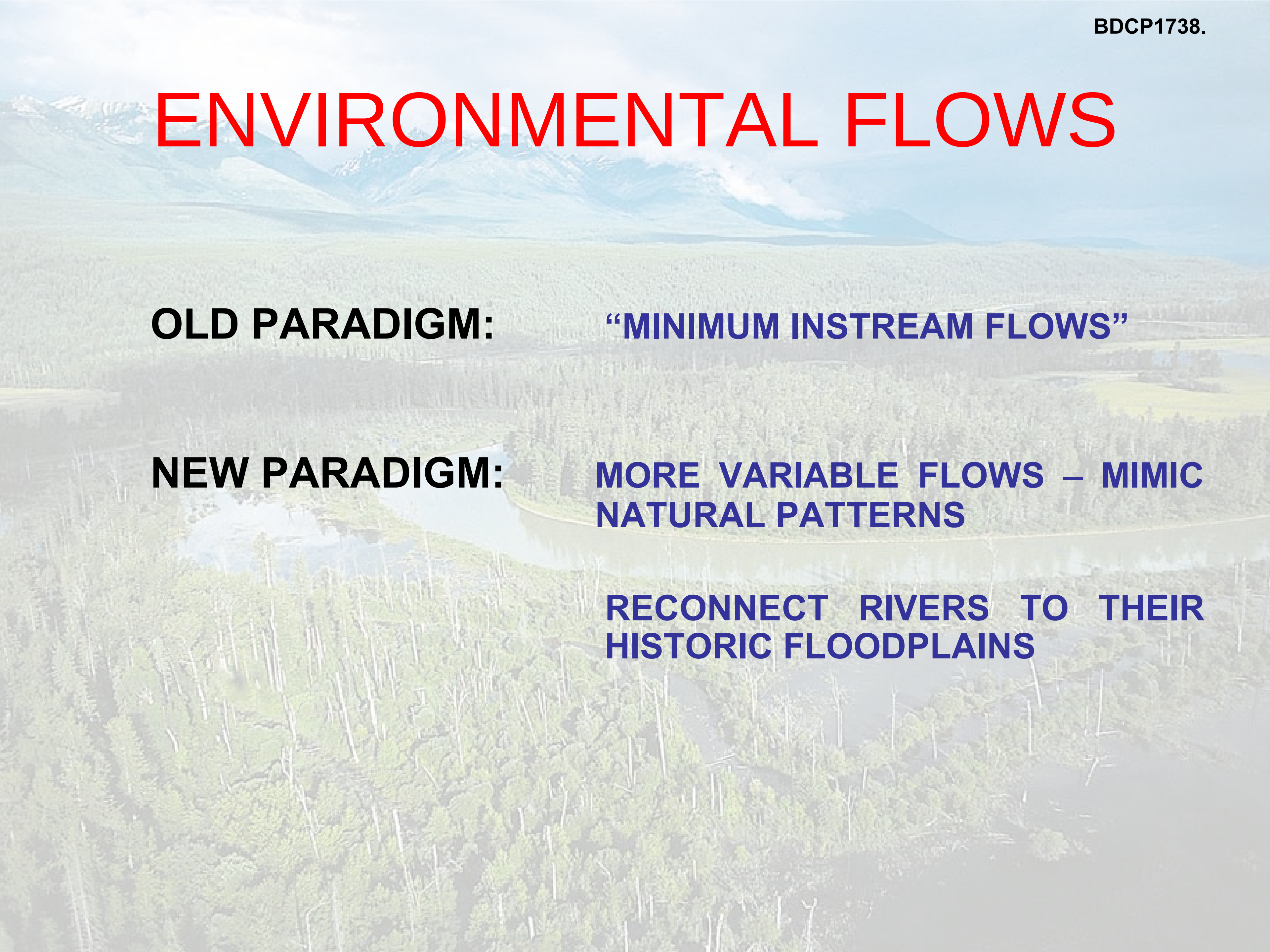


STORAGE RESERVOIRS IMPAIR NATURAL FLOWS IN TWO WAYS

1. FLOW DEPLETION
2. FLOW ALTERATION

COMBINED EFFECTS: FRESHWATER ECOSYSTEMS ARE THE MOST IMPAIRED ON THE PLANET

= EXTINCTION CRISIS



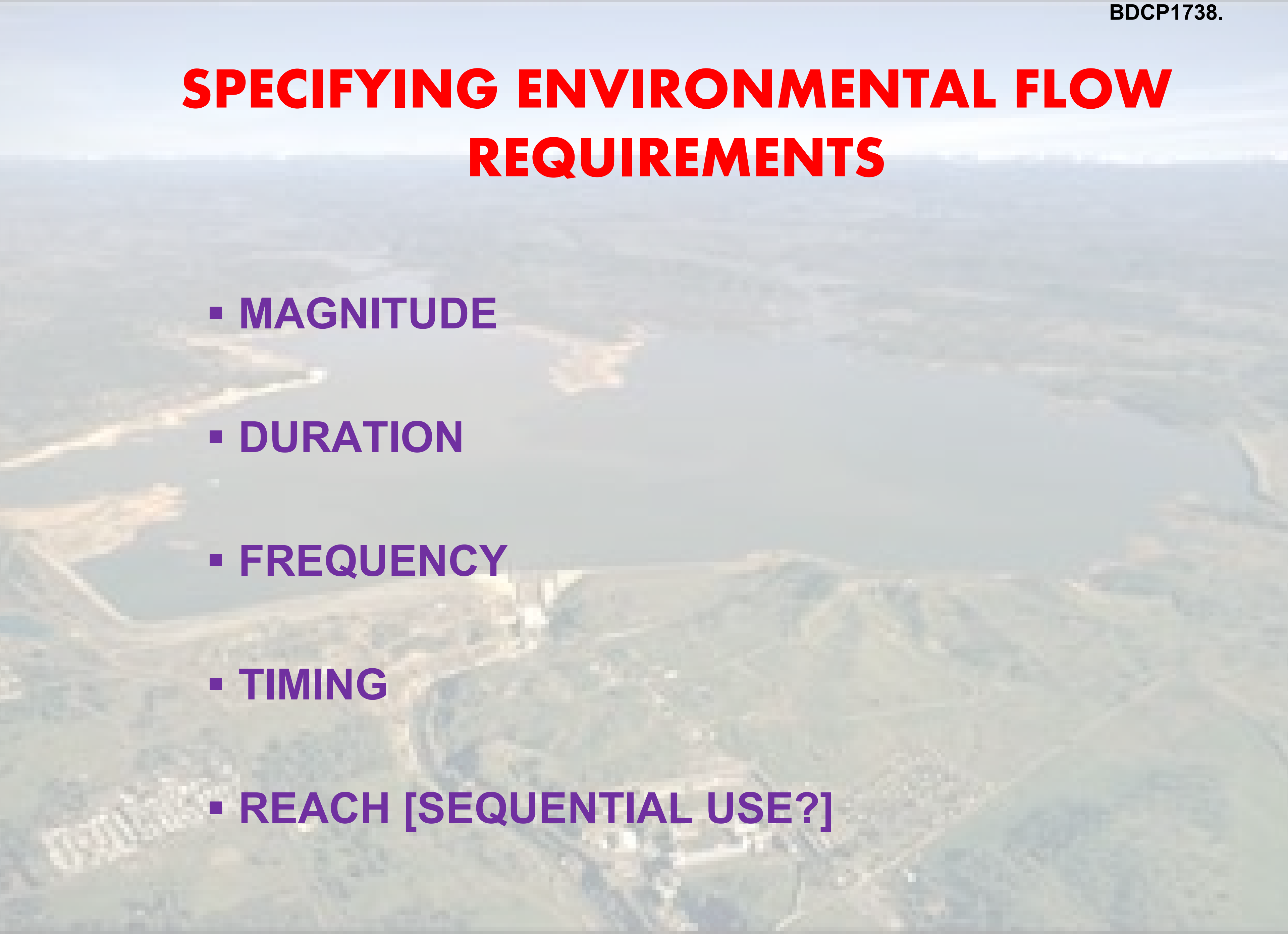
ENVIRONMENTAL FLOWS

OLD PARADIGM: “MINIMUM INSTREAM FLOWS”

NEW PARADIGM: MORE VARIABLE FLOWS – MIMIC NATURAL PATTERNS

RECONNECT RIVERS TO THEIR HISTORIC FLOODPLAINS

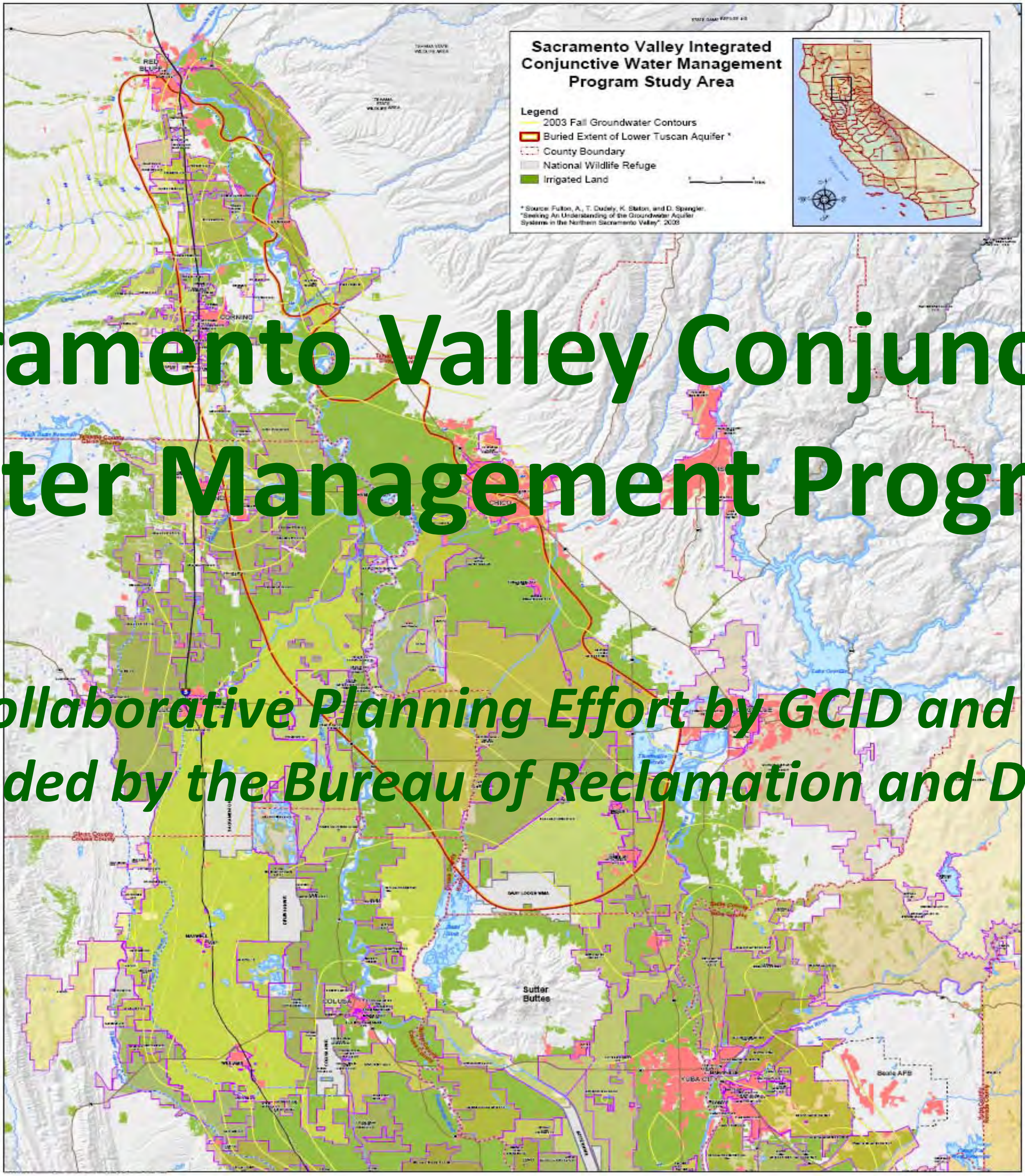
SPECIFYING ENVIRONMENTAL FLOW REQUIREMENTS



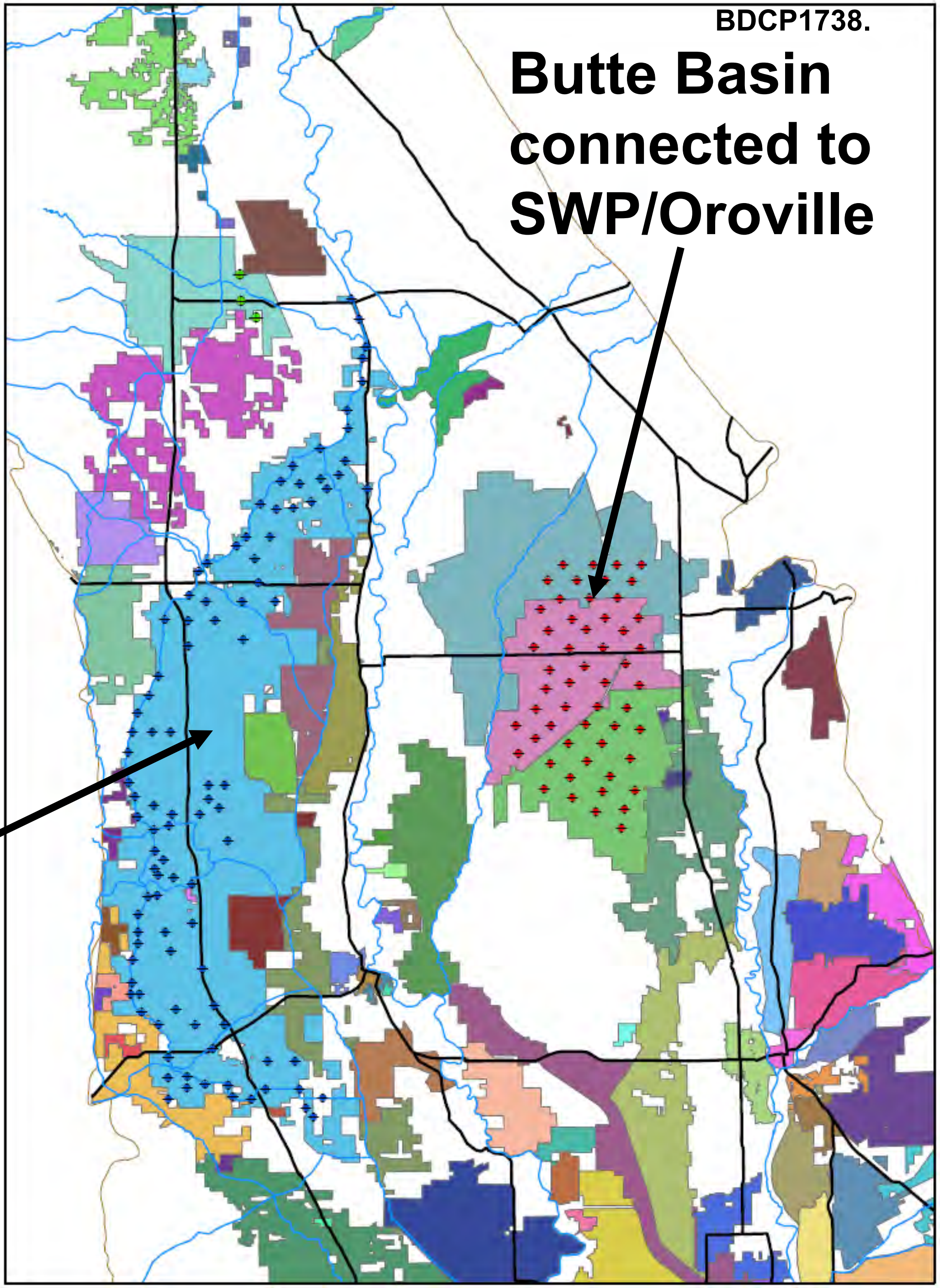
- MAGNITUDE
- DURATION
- FREQUENCY
- TIMING
- REACH [SEQUENTIAL USE?]

Sacramento Valley Conjunctive Water Management Program

A Collaborative Planning Effort by GCID and NHI
Funded by the Bureau of Reclamation and DWR



Two Promising Sites Identified

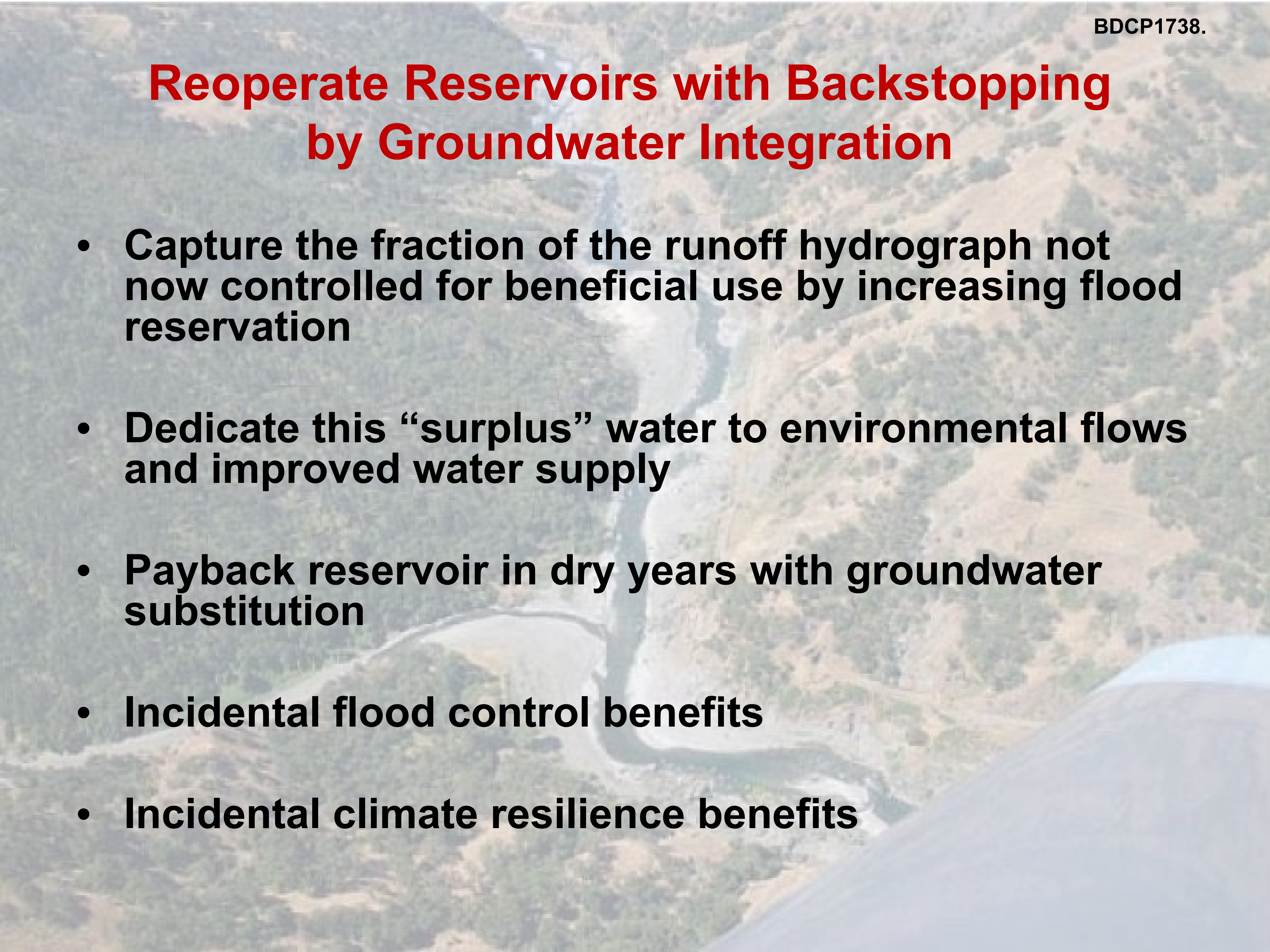


Butte Basin connected to SWP/Oroville

Glenn-Colusa ID connected to CVP/Shasta

Environmental Flow Objectives

- Geomorphic
  - Single day large event
  - February or March
- Riparian establishment
  - Five day large flow with 60 day recession
  - April start
- Flood plain inundation
  - Single day large event with 45 day recession
  - Between February and April
- Spring pulse flow
  - Simulate more natural spring runoff period

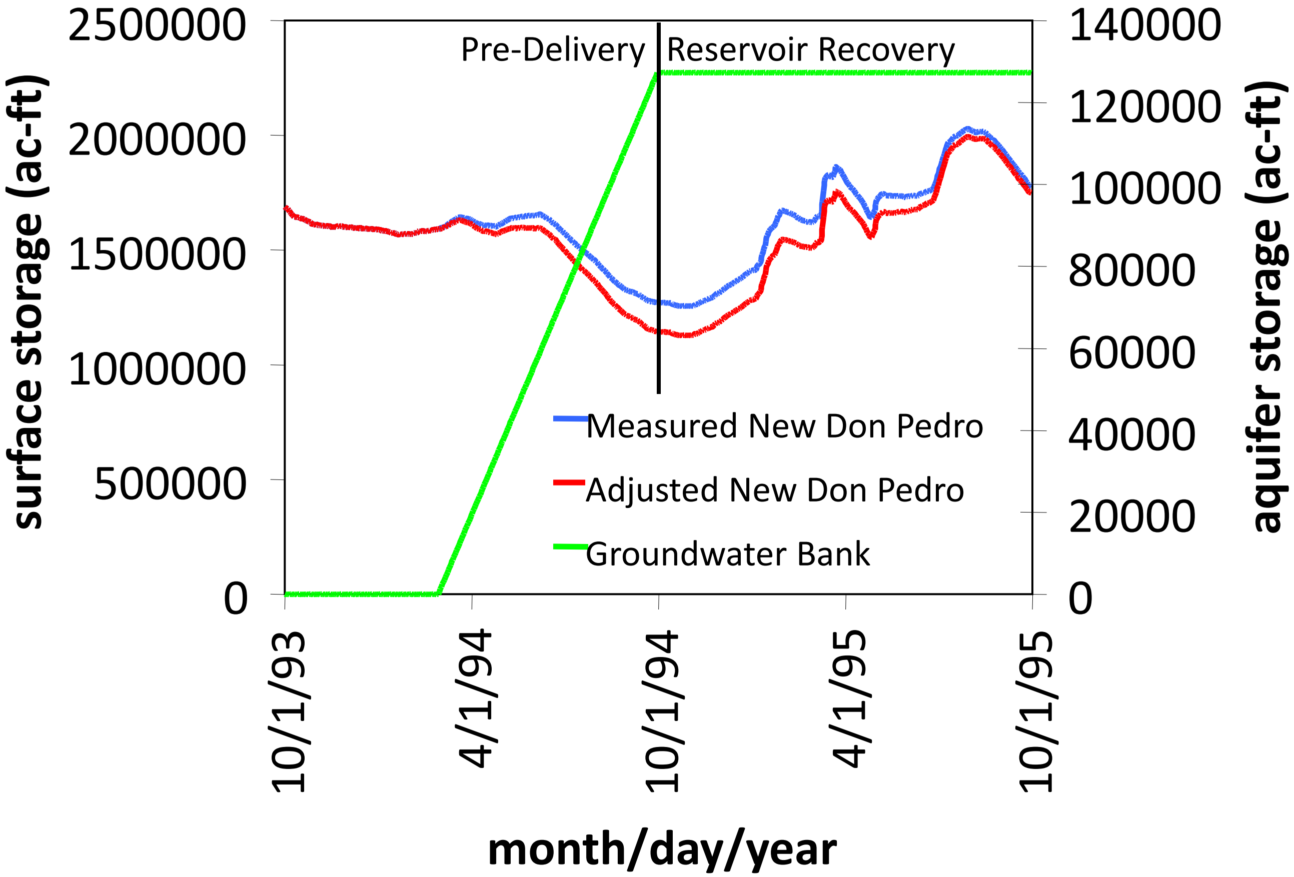


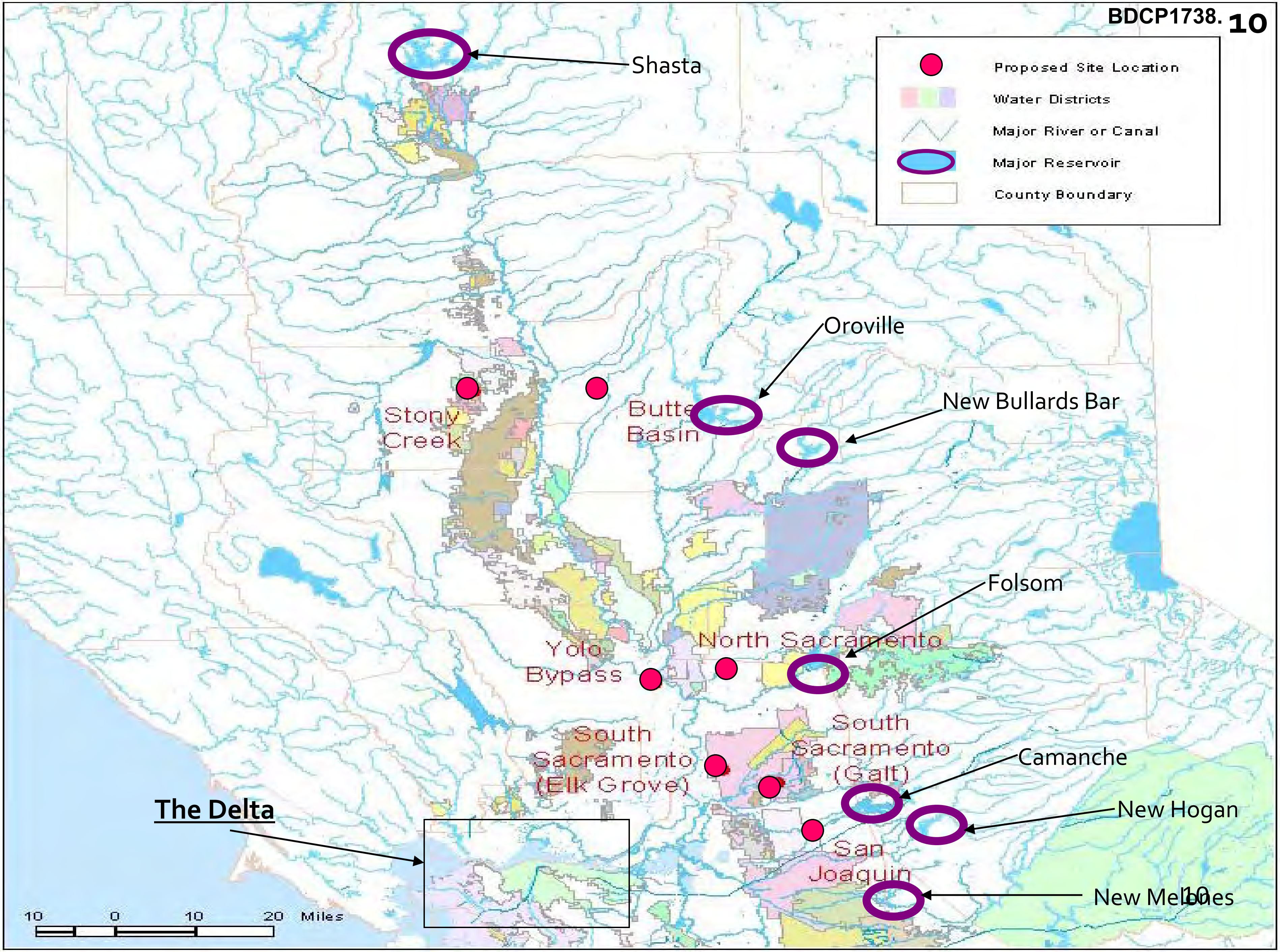
Reoperate Reservoirs with Backstopping by Groundwater Integration

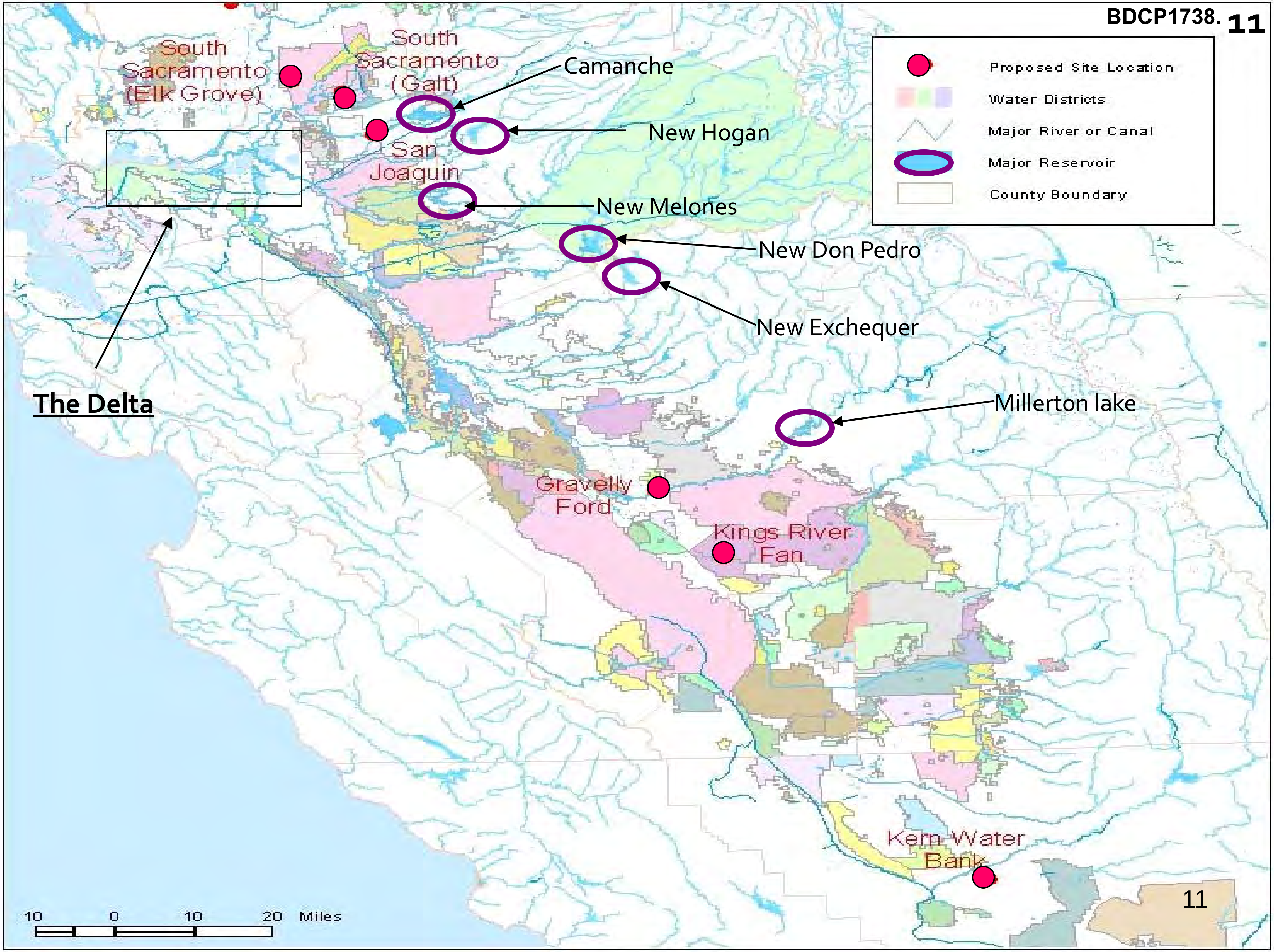
- Capture the fraction of the runoff hydrograph not now controlled for beneficial use by increasing flood reservation
- Dedicate this “surplus” water to environmental flows and improved water supply
- Payback reservoir in dry years with groundwater substitution
- Incidental flood control benefits
- Incidental climate resilience benefits

Modes of Groundwater Banking

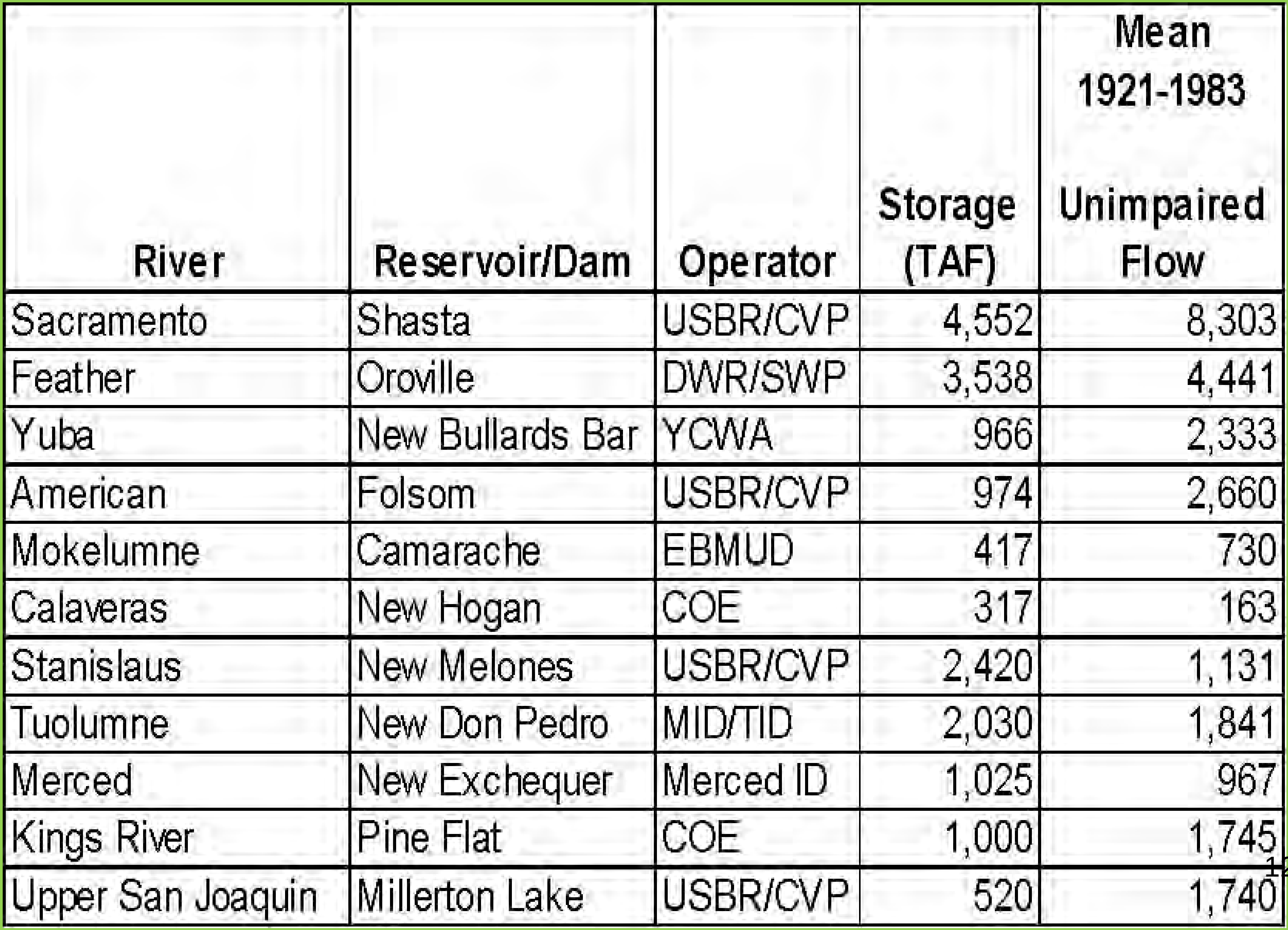
NHI Approach




Shasta
● Proposed Site Location
Water Districts
Major River or Canal
Major Reservoir
County Boundary
Oroville
New Bullards Bar
Stony Creek
Butte Basin
Folsom
Yolo Bypass
North Sacramento
South Sacramento (Elk Grove)
South Sacramento (Galt)
Camanche
New Hogan
San Joaquin
New Melones
The Delta
10 0 10 20 Miles


South Sacramento (Elk Grove)
South Sacramento (Galt)
Camanche
New Hogan
San Joaquin
New Melones
New Don Pedro
New Exchequer
The Delta
Millerton lake
Gravelly Ford
Kings River Fan
Kern Water Bank
Proposed Site Location
Water Districts
Major River or Canal
Major Reservoir
County Boundary
10
0
10
20
Miles

Reservoirs, Ownership, and Capacity



River	Reservoir/Dam	Operator	Storage (TAF)	Mean 1921-1983 Unimpaired Flow
Sacramento	Shasta	USBR/CVP	4,552	8,303
Feather	Oroville	DWR/SWP	3,538	4,441
Yuba	New Bullards Bar	YCWA	966	2,333
American	Folsom	USBR/CVP	974	2,660
Mokelumne	Camarache	EBMUD	417	730
Calaveras	New Hogan	COE	317	163
Stanislaus	New Melones	USBR/CVP	2,420	1,131
Tuolumne	New Don Pedro	MID/TID	2,030	1,841
Merced	New Exchequer	Merced ID	1,025	967
Kings River	Pine Flat	COE	1,000	1,745
Upper San Joaquin	Millerton Lake	USBR/CVP	520	1,740

Average Annual Yield Estimates for Eleven Regulated Tributaries of the Central Valley

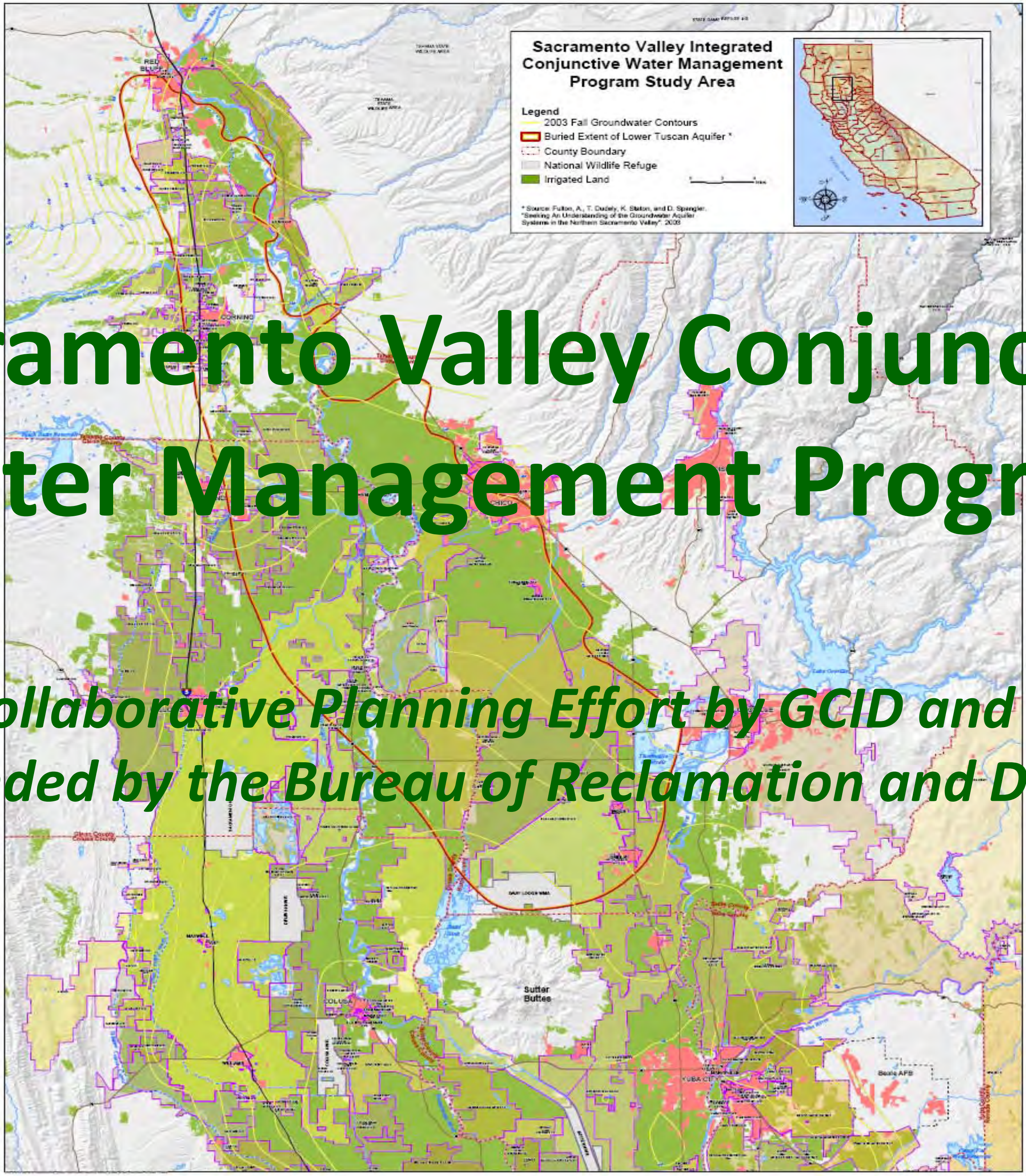
River	Conjunctive Use Re-Operation (TAF)
Sacramento	196.8
Feather	126.9
Yuba	144.5
American	80.4
Mokelumne	69.4
Calaveras	25.4
Stanislaus	65
Tuolumne	77.9
Merced	108.1
Upper San Joaquin	100
Pine Flat Reservoir	108
TOTAL	1102.4

Factors Taken Into Account

- Pre-existing rights & entitlements
- Prescribed environmental flows
- Temperature regulation

Factors NOT Taken Into Account

- Delta transfer constraints



Sacramento Valley Conjunctive Water Management Program

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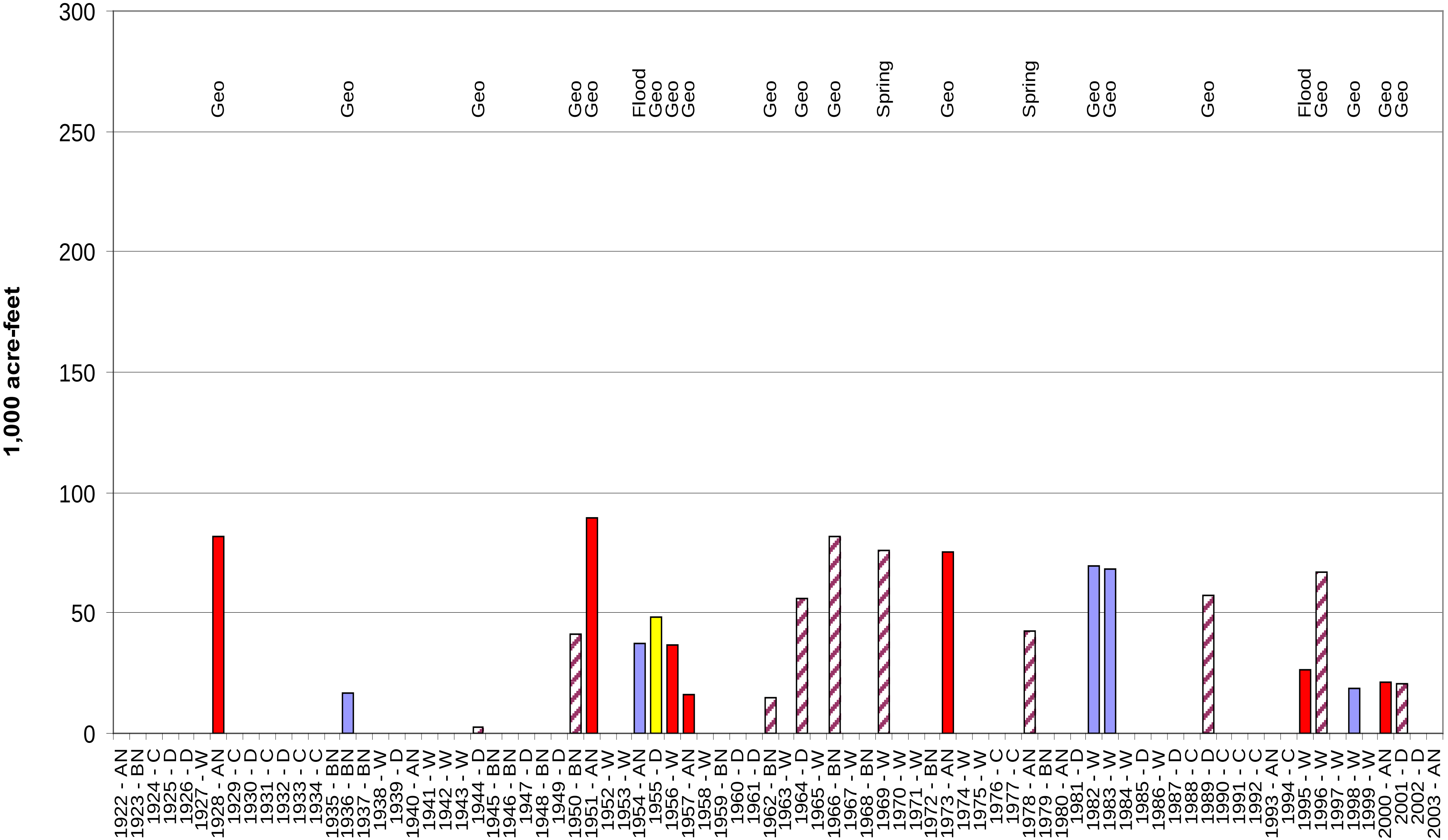
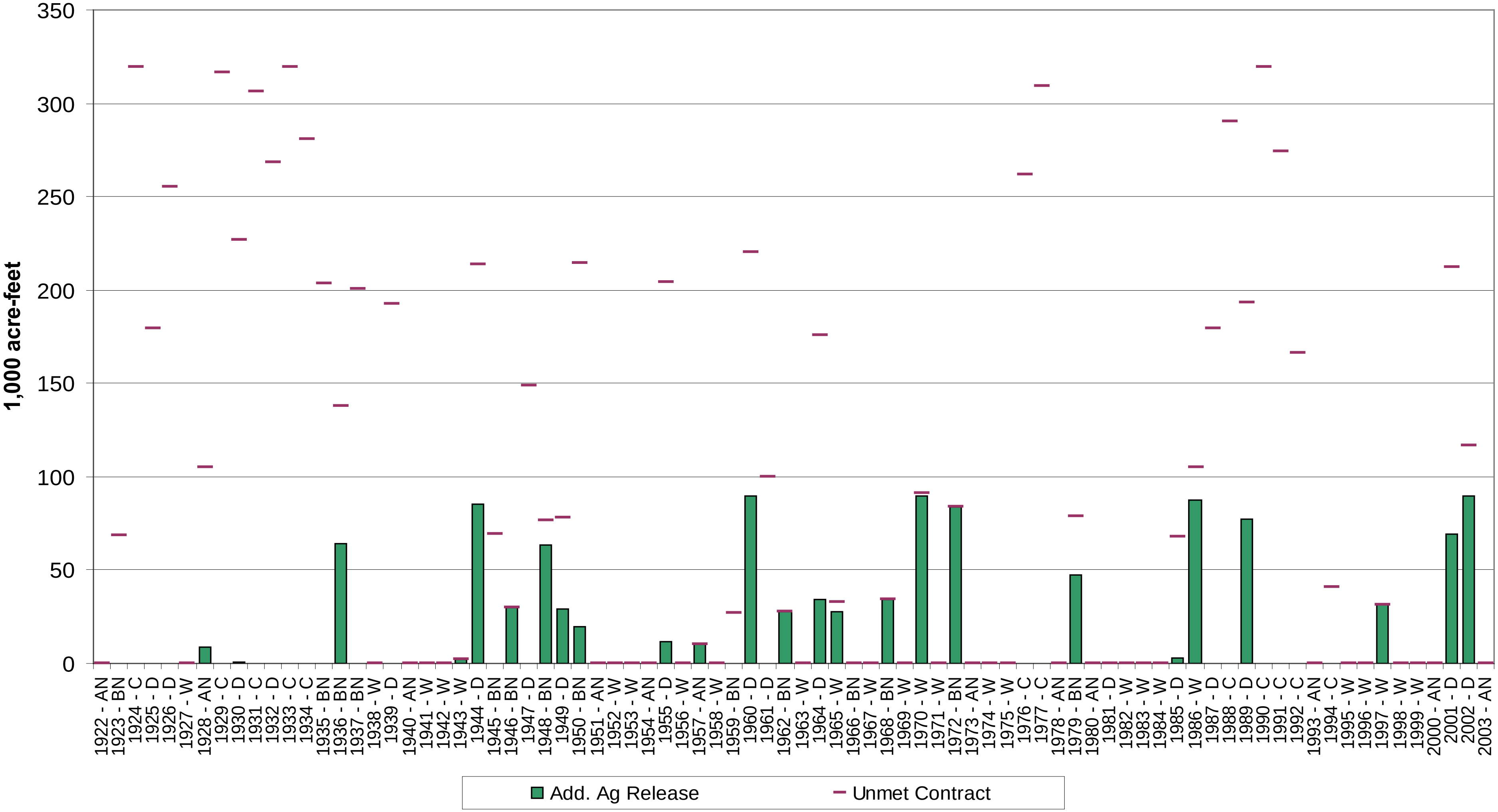
BDCP1738.

Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Environmental Flow Releases

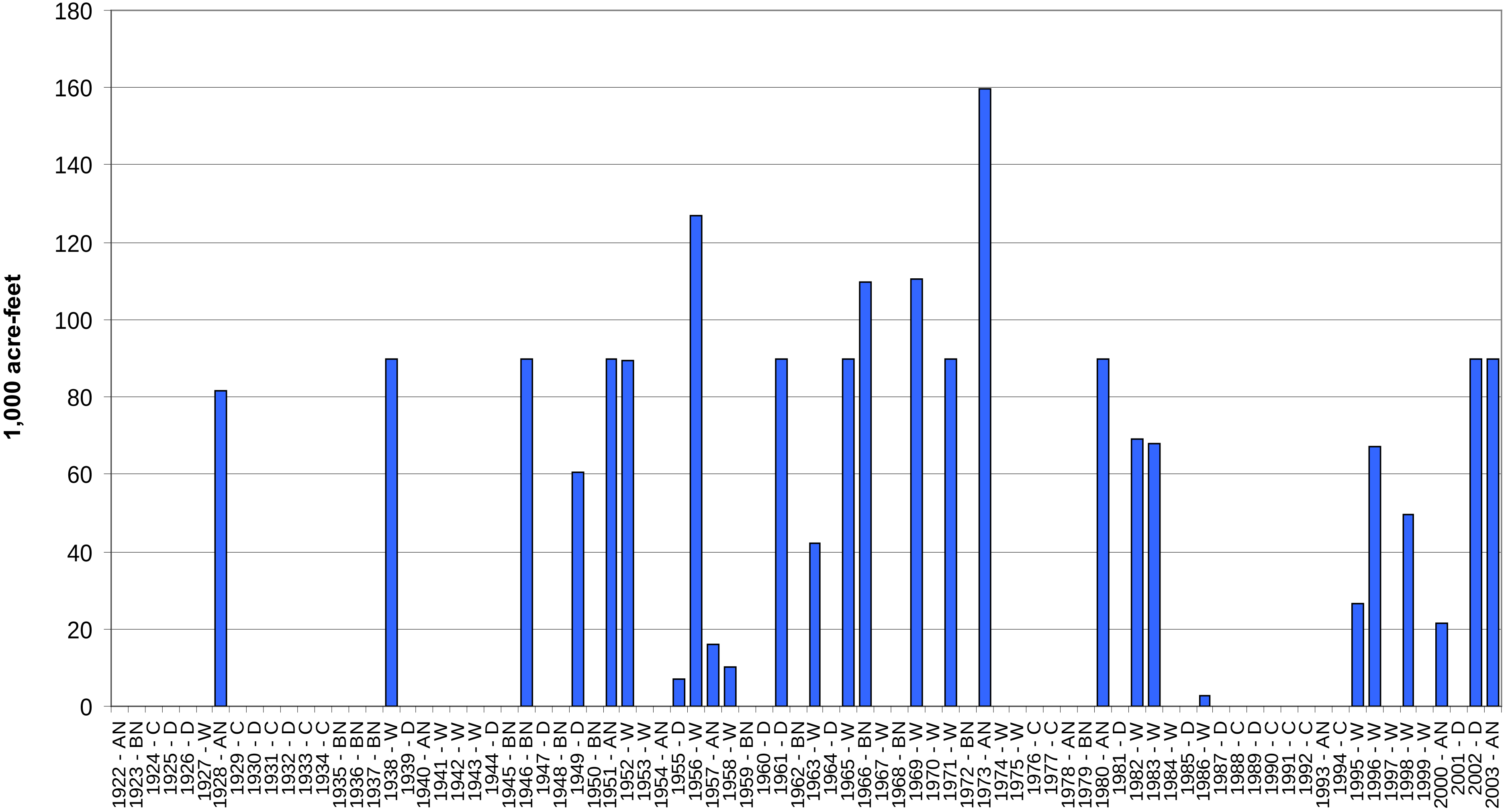


Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Sac River Agricultural Deliveries

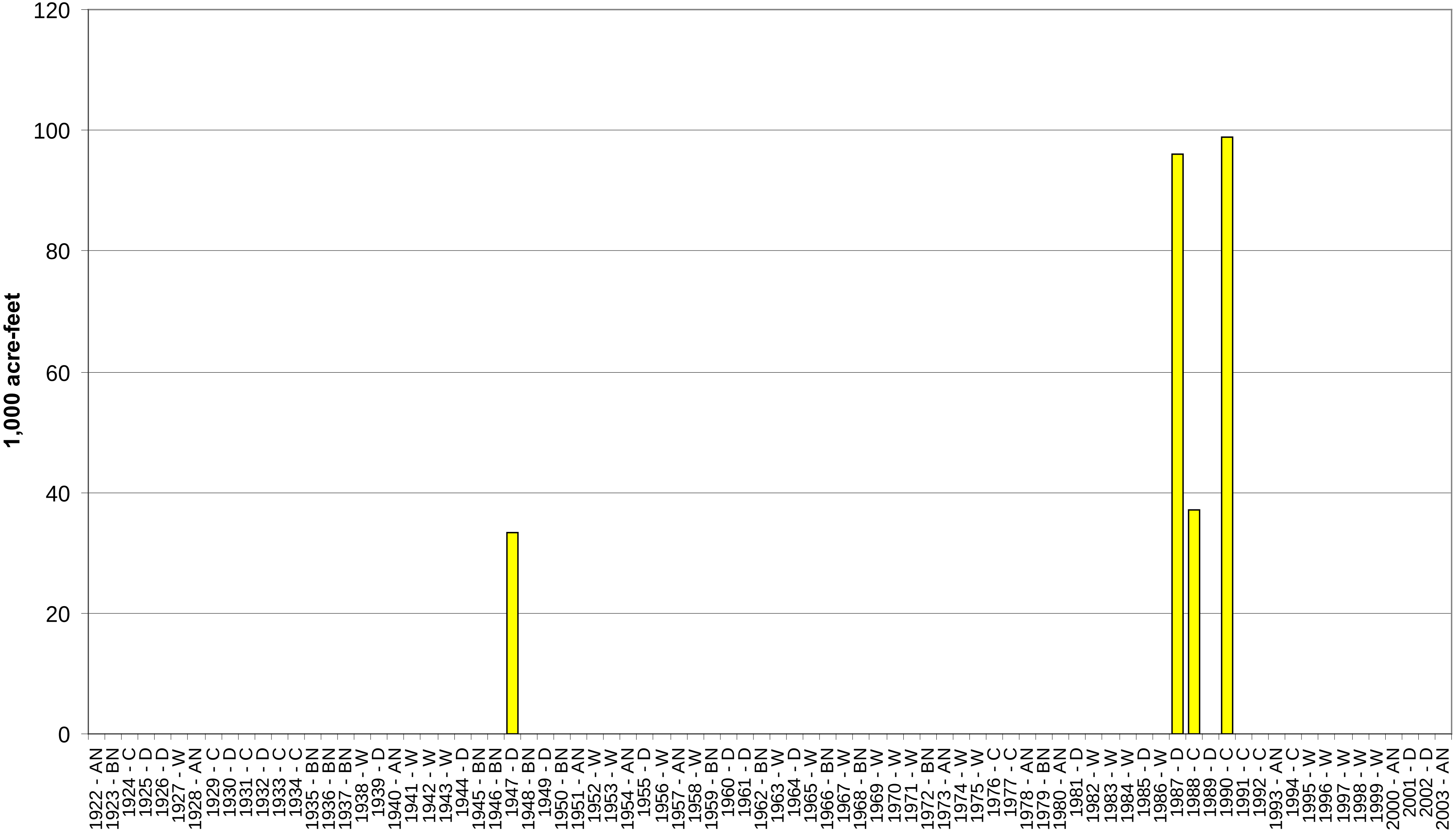


BDCP1738.

Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Refill from Surplus Surface Water



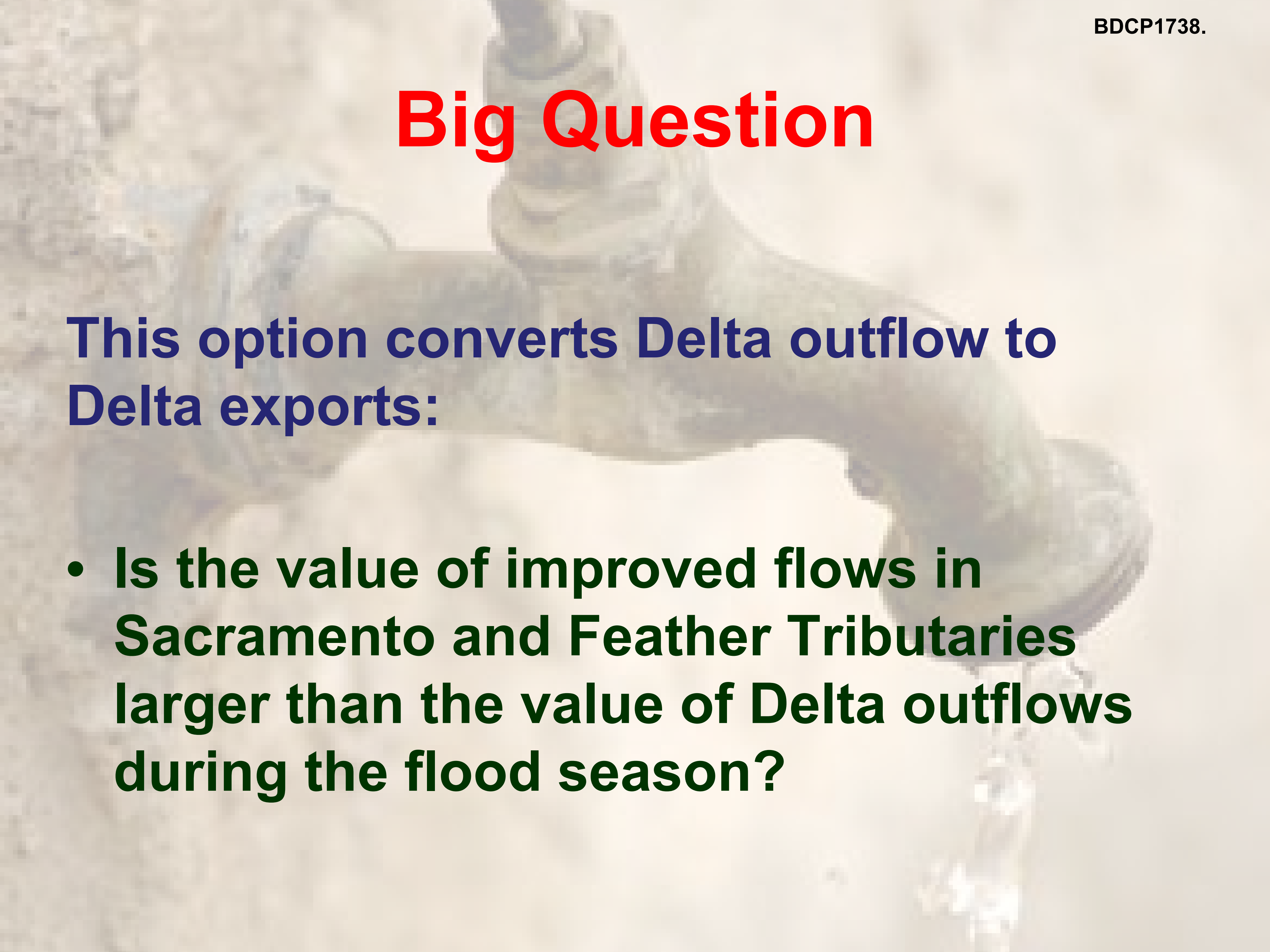
Scenario 1—CVP/Shasta
100 TAF Pumping Capacity in GCID
Refill from Groundwater Pumping



Why South of Delta GW Banking is Promising

- Avoid impacts on Sac Valley GW Users
- Extract and use banked water at times of greatest need and economic value
- No increase in Sac Valley exports
- Avoid operational losses for IDC by-pass flows by “riding on the back” of PRE exports

Big Question



This option converts Delta outflow to Delta exports:

- Is the value of improved flows in Sacramento and Feather Tributaries larger than the value of Delta outflows during the flood season?

Fish don't just need water-- they need a river!